Water Powers of Manitoba, Saskatchewan and Alberta

Leo G. Denis and J. B. Challies

Commission of Conservation
Canada

Commission of Conservation

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Commission of Conservation
Canada

COMMITTEE ON WATERS AND WATER-POWERS

WATER-POWERS
OF
MANITOBA, SASKATCHEWAN
AND
ALBERTA

by
LEO G. DENIS, B. Sc., E. E.
Hydro-Electric Engineer to Commission of Conservation

Additional date respecting Water-Powers of Southern Manitoba and Bow River by

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Committee on Waters and Water-Powers

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To Field Marshal, His Royal Highness Prince Arthur William Patrick Albert, Duke of Connaught and of Strathearn, K.G., K.T., K.P., &c., &c., Governor General of Canada.

May it Please Your Royal Highness:

The undersigned has the honour to lay before Your Royal Highness the report of the Commission of Conservation on the "Water-Powers of Manitoba, Saskatchewan and Alberta."

Respectfully submitted

CLIFFORD SIFTON

Chairman

Ottawa, May 1, 1916.

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Sir:—I have the honour to transmit herewith a report on the "Water-Powers of Manitoba, Saskatchewan and Alberta." In the report on "Water-Powers of Canada," published in 1911, it was announced that, owing to the paucity of published or available information respecting Manitoba, Saskatchewan and Alberta, it would be necessary to institute a reconnaissance survey of the water-powers of these provinces.

This volume contains the result of reconnaissance surveys of the water-powers of Manitoba, Saskatchewan and Alberta, together with portions of the Yukon and Northwest Territories, by Leo G. Denis, B. Sc., E. E., of the Commission of Conservation.

We are indebted to Mr. J. B. Challies, C. E., M. Can. Soc. C. E., Superintendent of the Dominion Water Power Branch, Department of the Interior, for the reports on the water-powers of Southern Manitoba and Alberta also regarding the Bow river basin above Calgary.

Respectfully submitted

JAMES WHITE
Assistant to Chairman

Sir Clifford Sifton, K.C.M.G.
Chairman
Commission of Conservation

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Commission of Conservation

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OF

Manitoba, Saskatchewan and Alberta

INTRODUCTION

IN the report on "Water-Powers of Canada," published by the Commission of Conservation in 1911, the subject was treated in a fairly complete manner with regard to the eastern provinces, but the information covering the Prairie Provinces and British Columbia was admittedly very incomplete, and the Commission, then, decided to publish, later, more exhaustive reports on the water-powers of those portions of the Dominion which had not been treated in detail in the above mentioned publication.

The present report covers the portion of Canada embraced in the three Prairie Provinces together with certain portions of the Yukon and Northwest Territories. When the compilation of "Water-Powers of Canada" was undertaken the information respecting water-powers in the Prairie Provinces was very limited, and, except explorations by the Geological Survey, preliminary work of the Dominion Water Power branch and some scattered information available through the courtesy of consulting engineers or private corporations, little or no data relating to the subject were obtainable. This lack of information may be attributed to several causes, chief among which, possibly, is the relatively recent development of this portion of Canada; moreover, this development was more along agricultural than industrial lines, although water-power is useful to both; and, lastly, the importance of water-power resources has only been appreciated since the advent of high-tension transmission of electrical energy, coupled with the great industrial tendency to replace hand labour by mechanical energy.

The Dominion Government controls the water resources of the Prairie Provinces and, during the past three or four years, has been particularly active in investigating them. The Water Power branch of the Department of the Interior administers the water-powers which come under the jurisdiction of the Dominion Government, and has not confined itself to the regulation and supervision of proposed developments. In the territory under its jurisdiction it has sent out field parties to investigate many of the water-powers and to

establish numerous gauging stations, where regular observations are taken. This branch has been in active operation since 1908, and, during the past three years, has covered most of the rivers in the southern portion of these provinces. Particular attention was paid to the Winnipeg river, in eastern Manitoba, and to the Bow river and adjacent basins on the Rocky Mountain slope. Reports on these two districts have been prepared, under the supervision of Mr. J. B. Challies, Superintendent of the Dominion Water Power branch, and have been incorporated in the present report.

The Irrigation branch of the Department of the Interior has also been actively investigating the water resources in certain portions of these provinces. Field investigations and irrigation surveys of various characters had been carried on since 1894, but systematized investigation really began with the organization of the Irrigation branch in 1908. The progress reports published annually contain general information respecting streams investigated, together with results of stream measurements, which have become a distinct feature of the work. Much information gleaned from these reports has been incorporated in the present volume.

The southern or more settled portion of the Prairie Provinces is fairly well covered by the work of these two branches of the Department of the Interior. As the northern portion had not been investigated by any other organization, the Commission of Conservation undertook exploratory surveys of the principal rivers in this region, the investigations covering the Athabaska, Peace, Slave, Nelson and other smaller rivers. The rivers were traversed, generally, by canoe, the descent of the falls or rapids being levelled, flow measurements taken, and other details connected with the feasibility of development noted. The results of these surveys are embodied in the present report.

For the rivers further north, information was obtained from the reports of explorations made by the Geological Survey, the data being compiled from reports and maps of this branch and from the explorers' notes, which were courteously placed at the disposal of the Commission. In this region, generally speaking, the information available respecting the different rapids and falls is confined to a statement of the vertical descent, but, in many cases, the geological formation and distances from head to foot of the rapids are also given, as this information may assist in deciding the feasibility of development.

The southern portion of the Prairie Provinces may be divided into three sections, having widely different water-power characteristics:

1. The portion in the vicinity of lake Winnipeg, in the east.

2. The more level portion in the centre.
3. The mountain and foothill country in the west.

In the first, or eastern portion, the Winnipeg river is the main feature. This river, with its drainage area of 53,500 square miles, has a well-regulated flow and affords numerous water-powers of immense value. Two of the sites have already been developed and supply the city of Winnipeg with its electrical energy, while construction work on some of the other sites has either been commenced or is on the eve of starting. Numerous smaller streams in this eastern portion also afford splendid opportunities for water-power development, some of them being actually utilized on the Minnedosa and Shell rivers. This section also includes the Grand rapids of the Saskatchewan river, where a head of 80 feet is available, affording an exceptionally good power site.

The second, or middle portion, is traversed by two main arteries, the North Saskatchewan and South Saskatchewan rivers. These, with their main tributaries, flow with an even, moderate current with no concentrated descents of importance. Although, strictly speaking, this portion is not entirely without water-powers, yet the possibilities of such are rather unfavourable. In almost every case the total head would have to be created and several proposed developments have already been abandoned on account of the high cost of development.

The third portion, of which the Bow river is typical, has many valuable water-powers. There are none of unusual size, those on the Bow river itself probably being the most important. The slopes of the streams, characteristic of a mountainous region, are generally very steep, and, while the flow of water is subject to fairly large variation, good opportunities for storage and artificial regulation are afforded.

With regard to special measures taken by the Dominion Government in connection with the administration of the water-powers in the southern portion of the Prairie Provinces, the setting aside of the eastern slope of the Rocky mountains as a forest reserve, known as the Rocky Mountains Forest Reserve, may be mentioned first. This step was taken on the recommendation of the Commission of Conservation, and, as a result, an area of 17,900 square miles has been assured protection from such denudation as has already taken place in some of the older provinces. All the upper tributaries of the North Saskatchewan and South Saskatchewan rivers have their sources within this area, and the beneficial effect of conserving its forest cover is evident as far east as the Grand rapid on the main Saskatchewan river. With a similar object in view, the Commission has recently

recommended that steps be taken to segregate, as a forest reserve, the upper portion of the drainage area of the Winnipeg river. This recommendation will doubtless be acted upon shortly, and will prevent the useless dissipation of the present facilities which this district offers for storage and conservation of run-off. This step is of particular significance, as the Winnipeg river affords the only water-powers of importance susceptible, under present conditions, of being economically developed and transmitted to the city of Winnipeg and the surrounding district, an area that will undoubtedly become thickly populated within a very few years.

Among other measures may be mentioned, also, the policy adopted by the Dominion Government, of reserving, on the recommendation of the Superintendent of the Water Power branch, all vacant Dominion lands which may be valuable for the development of water-power. The land is thus held from the hands of speculators and kept for promoters of *bona fide* power development. Reservations of this character have already been made on the Winnipeg, Saskatchewan, Bow, Elbow, Athabaska, Peace and other rivers.

All the water-powers in the Prairie Provinces come under the direct control of the Dominion Government, water-power rights being granted under special regulations. The full text of the regulations is given as Appendix VI, p. 301, from which it may be seen that all water-powers under federal control are "licensed" on strict conditions and, before the license is issued for any water-power site, or for the purpose of storing water, the application must go through three different stages:

1. The plans must be submitted to and approved by a competent staff (the Water Power branch of the Interior Department), which has been established for the purpose of investigating proposed water-power developments, from both engineering and economic standpoints, particularly from the view-point of their maximum efficiency in conjunction with other power sites on the same or tributary rivers.

2. Once the plans have been approved, construction work may proceed under Government supervision.

3. After the construction work is completed the license is granted for a limited period, the Government reserving the following, among other, rights:

(*a*) The privilege of refusing to renew the license;

(*b*) The right of demanding the development of power sufficient to satisfy public demand up to the full amount obtainable from the water-power under license;

(*c*) The right of the Board of Railway Commissioners of Canada to fix the rates for power charged to the public.

CHAPTER I

Winnipeg River*

METERING STATIONS ESTABLISHED BY THE MANITOBA HYDROGRAPHIC SURVEY

Name of River	Situation	When established	Remarks
Winnipeg	Otter fall		Gauge readings were commenced at Point du Bois in Jan., 1907, and these records used in connection with later discharge measurements at the two stations
Winnipeg	Slave falls		
Whitemouth ...	Whitemouth	May, 1912	

Water-Powers in Southern Manitoba

That Manitoba is richly endowed with numerous water-powers has been generally known, but, prior to the investigations of the Water Power branch of the Department of the Interior, their extent and magnitude had been only approximated.

Recognizing the great value of such powers, and with a view to the power requirements of both the present and the future, a complete study has been made of certain power rivers, and is being made of all others throughout the province. In such studies it is the aim of the Department to form a comprehensive scheme, contemplating the maximum development of the total head available upon each river.

The great power possibilities of Manitoba are due to the geological and topographical features of the province. The central portion of Manitoba acts as a collecting basin for the waters from an immense drainage area. This vast area extends from the Rocky mountains practically as far eastward as lake Superior; it also comprises a portion of the northern United States and reaches into the northerly lands of western Canada.

* Practically the whole of this chapter was compiled from field investigations and stream flow study by the engineers of the Water Power branch of the Department of the Interior, under the direction of Mr. J. B. Challies, Superintendent. The description of power plants was obtained directly from the officials operating same. See also *Water Resources Paper No. 7,* Department of the Interior.

As these waters reach the central portion of the province, a depression occurs between the prairie steppes and the Laurentian plateau, through which an extensive fall is available for power development. Lake Winnipeg forms the reservoir into which is collected practically all the run-off from the above-described drainage area. From this lake to Hudson bay the flow is concentrated in the Nelson river, in which a descent of 713 feet occurs.

From the foregoing it is apparent that the major portion of the powers contained in the basin are concentrated within the lower portion of the drainage area, or, more particularly, in Manitoba.

The powers are naturally separated into two divisions, *viz.*, those occurring on the rivers draining *into* lake Winnipeg, which are situated in the older or southern portion of the province, and, secondly, the powers which occur in the northern portion, lying in the drainage *from* lake Winnipeg.

It should be noted that, while on many rivers possible power concentrations have been investigated, and estimates of the available power are given for various sites, yet, as future investigations will show, additional power may be available on such rivers. Again, in the case of other rivers, no surveys to determine the extent of concentration available have been made, as yet, and, in these cases, where a record of the flow has been obtained, an estimate is made of the power available per foot head. In many cases the power has been estimated both for the extreme minimum flow and for the lowest monthly mean flow of the highest six months of the year, as obtained from the present record of discharges.

The horse-power has been calculated for a turbine efficiency of 80 per cent, while no estimate has been made of the power available during short periods of high or peak loads, since this would be impossible without a knowledge of the purposes for which the power might be utilized. The powers on the Winnipeg river have been considered on a 75 per cent efficiency basis, as explained later.

The data for these tables, and also for the more detailed description of the rivers, as given in the following chapters, have been secured in the field by the Manitoba Hydrometric and Power surveys, and office compilations of the same have been made in Winnipeg and Ottawa.

Rainfall, Evaporation and Run-off

General.—Two main factors enter into the investigation of any possible power development—the head and the flow available. While the first of these is obtainable through field survey, and a knowledge of the extreme and average stages of river level, the second comprises an extensive

study of the flow, which, dependent on natural conditions, varies not only with the season and year, but also with the topography and character of the drainage area. Primarily, all water carried by rivers comes from precipitation. Of this a portion evaporates, a portion enters the soil, and is either absorbed by plant growth, or, by ground flow reaches the rivers or lakes, while the remainder finds its way into streams as surface flow or run-off.

Precipitation.—While the record of the run-off from a drainage area is of first importance in the question of power development, the records of the precipitation are also of extreme value, inasmuch as, if of a more extended period than those of the run-off, they indicate the high and low range of flow which may be expected. In like manner, precipitation records, in a drainage basin in which no discharge measurements are available, can be used for the estimation of the flow based on the precipitation and run-off records of an adjacent area.

Throughout the southern portion of the province of Manitoba, such records have been obtained by the Meteorological Service of the Marine and Fisheries Department, and these records are tabulated below.

It is well known that the precipitation not only shows a variation from season to season, but, also, that a record extending over a few years is not sufficient to give the mean annual precipitation; for this purpose, a period or cycle of long term should be considered. As there are only a few stations in Manitoba at which long term records have been obtained, it is necessary to carry out some system of compensation for the shorter records of the adjacent stations. The records of the precipitation at the long term stations have the same general features from period to period. Assuming that the variations in precipitation are similar at both long and short term stations, the precipitation at the short term stations has been estimated from the records at an adjacent long term station. The precipitation, together with the duration of the record, is given for various stations throughout the province. The ratio of all short term records has been computed from the nearest long term station, as tabulated, and a compensated annual mean for the station has been calculated.

MANITOBA PRECIPITATION RECORDS

(This table has been compiled from the Meteorological Service records. Ten inches of snow have been assumed equal to 1 inch of rainfall.)

Station	Elevation	Duration of record	Years	Annual mean, inches	Long term mean based on record at	Probable ratio of precipitation in this period to long term mean	Compensated annual mean for this station
						Per cent	
Almasippi		1903—1912	10	20.90	Winnipeg	100	20.9
Asessippi	1,459	1886	1	13.52	Minnedosa	65	18.3
Adelpha	1,886	1888—1912	1	12.25	Bottineau, N.D.	86	14
Brandon	1,260	1885—1912	21	17.16		100	17.2
Birtle	1,707	1884	1	25.40	Hillview	130	17.8
Barnardo		1891—1905	9	16.80	Hillview	122	13.1
Berens River	720	1908—1912	5	21.22			
Beausejour	816	1886—1888	3	15.09	Winnipeg	52	22.3
Burnside	874	1886—1890	4	14.95	StonyMountain	70	19.4
Craigilea		1888	1	15.05	Winnipeg	78	18.4
Channel Island.		1890—1905	15	17.10	StonyMountain	73	21.7
Cartwright	1,529	1884—1912	15	19.82	Bottineau	123	15.3
Clarkleigh	819	1886—1888	3	18.10	StonyMountain	86	20.6
Carberry	1,262	1909—1911	3	17.07	Minnedosa	90	18.8
Clandeboye	742	1884—1888	4	16.72	StonyMountain	72	21.4
Elkhorn	1,640	1895—1901	4	17.81	Hillview	115	15.1
Emerson	797	1894—1898	3	21.67	Pembina, N.D	106	20.4
Eden	1,306	1884—1887	4	17.14	Minnedosa	74	21.6
Fort Ellice		1885—1891	7	15.25	Hillview	99	15.4
Gretna	831	1903—1910	8	18.67	Pembina, N.D.	94	19.8
Gilrad		1904—1905	2	11.77	Bottineau	93	12.6
Hillview	1,400	1891—1912	20	20	Minnedosa	114	17.2
Minnedosa	1,675	1881—1912	32	17.82		100	17.8
Morden	990	1888—1912	17	19.69	Pembina, N.D.	93	21.1
Norquay	798	1888—1912	16	19	Winnipeg	85	21.9
Oakbank	812	1886—1912	22	21.04		100	21
Oakdale Park	740	1905	1	18.48	Minnedosa	110	16.6
Por. la Prairie	857	1884—1908	14	17	Winnipeg	93	18.2
Pilot Mound	1,551	1887—1898	4	18.74	Pembina	93	20.1
Rapid City	1,600	1882—1912	15	17.65	Minnedosa	91	18.2
Russell	1,850	1884—1904	9	15.18	Hillview	89	16.8
St. Albans	1,060	1885—1912	25	17.66		100	17.7
Swan River	1,115	1901—1910	4	20.85			
Shell River		1884—1890	6	15.37	Minnedosa	89	16.9
Stony Mountain	775	1878—1909	22	17.64	Winnipeg	83	20.6
Turtle Mountain	2,150	1884—1904	12	21.92	Bottineau	141	12.9
Treherne	1,212	1910—1912	3	18.28	Winnipeg	93	19.6
Winnipeg	760	1873—1912	40	21.55		100	21.6
Kenora (Ont.)	1,091	1886—1912	9	22.41	Win'g, Pt. Ar.	93	24
Norway House	720	1896—1904	8	18.90			
York Factory	20	1875—1882	3	20.38			
Moosomin (Sask.)	1,892	1901—1905	3	17.39	Hillview	113	15.1
Saltcoats (Sask.)	1,736	1900—1903	4	15.69	Hillview	122	12.2
Pt. Arthur (Ont.)	615	1886—1912	27	23.08			

WINNIPEG RIVER—SILVER FALL

WINNIPEG RIVER—MAIN WEIR FOR PINAWA CHANNEL

Evaporation.—Of the tremendous losses due to evaporation from the ground surface very little is known. It is impossible to arrive at such losses by taking the difference between precipitation and run-off, as in this there would also be included the losses due to absorption by the soil and by vegetation, and, moreover, the rate of run-off does not depend solely upon the precipitation. It is known, however, that a variation does occur in the evaporation, depending upon many factors, including atmospheric conditions, geological and topographical features of the drainage basin, and the extent of forestation and vegetation.

A more complete study has been made of the evaporation from the water surface of lakes and rivers, the greatest use of such studies being in the investigation of storage and the losses which are likely to occur on such reservoirs through evaporation. That the losses on lake areas are very great, and often of greater extent than precipitation, is well known.

The Water Power branch, Department of the Interior, has initiated a comprehensive scheme of evaporation studies throughout the Prairie Provinces and in British Columbia. Arrangements have already been made for stations at the following points,—Kenora on the lake of the Woods; Point du Bois fall on the Winnipeg river; Saskatoon; Prince Albert, in connection with the proposed power development at Cole fall; Edmonton; Minnewanka lake, Rocky Mountains Park, in connection with a storage project of the Calgary Power Company; at Nelson, B.C., Kamloops, B.C., and Vancouver, B.C. One of these stations, that at Kenora, has been in operation for about two years, and very interesting and instructive data have been collected. The investigations will, however, have to be carried on for a period of three or four years before the results would justify publication.

Run-off.—While the volume of run-off or stream flow depends principally upon the amount of precipitation and the area of the basin drained, many other factors enter therein and are of extreme importance, such as the geological formation and topographic features of the drainage area, whether of sloping land tending to give a rapid run-off, or of low lying, swampy areas from which the flow is more or less uniform; it is also dependent upon the extent of the growth of timber and vegetation, together with numerous other factors.

While the studies of precipitation and evaporation and the physical features of a drainage area are valuable, the most accurate and reliable data with regard to run-off or stream flow are obtained by a systematic gauging and metering of the flow of the stream, to secure the continuous run-off, extending over sufficient time to obtain the

extreme fluctuations. The run-off of any stream varies not only from season to season, but also to such an extent from year to year that the same conditions rarely occur on a river in any two successive years. Records for a cycle of at least seven years are, as a rule, necessary to cover the yearly variation to be anticipated.

Not only is the study of the run-off of streams of great importance in the investigations of power possibilities, but it is also of extreme value in the investigation of possible reclamation of low lands through drainage, or the reclamation of arid lands through irrigation. Such a study is also necessitated on many rivers where schemes for the betterment of navigation are proposed.

Manitoba Hydrometric Survey

Prior to 1911 there had been no systematic or reliable gathering of data relating to the flow of the rivers in Manitoba. A few scattered discharge measurements had been made throughout the province, but not of sufficient extent to give information as to the continuous flow of any rivers as extending over various stages of their discharge. In 1911 a systematic study of the power possibilities of the Winnipeg river was inaugurated by Mr. J. B. Challies, Superintendent of the Water Power branch, Department of the Interior. The field work consisted of a detailed survey of the river and its power possibilities in Manitoba, and also included the establishment and maintenance of gauging stations thereon. In 1912 this work was extended to embrace a systematic study of the flow and power possibilities of all rivers throughout the province. For this extensive work the Manitoba Hydrometric Survey was organized, with Mr. D. L. McLean as chief engineer. The work is still being carried on under the supervision of the Water Power branch with Mr. M. C. Hendry as chief engineer. Numerous gauging stations were established on the rivers and streams throughout the province, and the collection and compilation of the data have been vigorously carried on.

Water-Powers of Winnipeg River*

It has long been recognized that there is an enormous reserve of potential water-power on the Winnipeg river within the province of Manitoba. The rapidity with which the existing developments on the river have been, and are being, increased to their capacity, and the active interest that has been taken in the undeveloped power sites of the river, have compelled the Dominion Government to give its water-power resources careful consideration. Within the past few years,

*See also *Water Resources Paper No. 3,* by J. T. Johnston, Chief Hydraulic Engineer, Water Power branch.

many applications for power privileges on this river have been presented to the Dominion Government; projects have been proposed for the utilization of various portions of the natural fall, some contemplating the combination of several falls by the concentration of their respective descents at one power site, and others simply proposing the utilization of the descent at a particular fall. These have been so varied and so conflicting, and, at the same time, supported by such reputable engineering advice, that the Government found it inadvisable to commit itself with respect to any further developments on the river until it had first secured a complete survey and investigation of the whole river, with a view to securing such information as would enable the authorization of developments which would contemplate the maximum utilization of the water-powers. These investigations were commenced early in 1911, under the consulting advice of J. B. McRae and J. R. Freeman. The field work has been carried on under D. L. McLean, S. S. Scovil and M. C. Hendry, successively. A study and analysis of the field plans by J. T. Johnston is published in *Water Resources Paper No. 3*. It outlines a comprehensive project of hydro-electric development for the Winnipeg river in Manitoba. It includes the proposed concentrations of the various separate falls on the river which have been designed to utilize all the natural fall and, at the same time, make each unit a component part of the development project for the whole river. These investigations have resulted in an economical and practical project for the power development of the river as required by the people of southern Manitoba.

Description of River and Drainage Basin

Winnipeg river is one of the most notable power rivers on the continent; it flows in a westerly direction, connecting the lake of the Woods with lake Winnipeg. The basin drained comprises an immense area of some 53,500 square miles. As is typical of Laurentian country, the area is dotted with innumerable muskegs and lakes, the latter varying in size from small ponds to the lake of the Woods, with an area of 1,500 square miles. Since practically the entire basin is of Laurentian formation, containing areas of overlying soil of glacial origin, certain general characteristics apply to the drainage basin as a whole. The country is rough and hilly, with large areas of rock outcrop. This latter feature applies in the main throughout the Winnipeg river, and lends itself to a characteristic formation throughout the river channel, which is of exceptional value in the interests of power development. The larger proportion of the river bed in the province of Manitoba consists of a

series of deep, cup-like basins, forming small, lake-like expanses, with little or no current. The river flow finds its way from these basins by falls and rapids over the rock formation, which is always in evidence at the outlets, and which forms both the means of egress from and the controlling feature of the basin water level. These falls form the natural power sites along the river.

A valuable timber growth, including spruce, tamarack, birch and pine, occurs throughout the whole district. Lumbering is carried on extensively, and, in addition, pulp and paper industries have been established at Fort Frances and Dryden. Notwithstanding the great extent of rock outcrop, considerable areas are available for farming, particularly in the Whitemouth and Rainy River districts. While there are several prosperous towns in the basin, such as Fort Frances, Rainy River and Kenora, the greater portion of the country is still unsettled.

The upper watershed reaches to the height-of-land separating the Atlantic drainage from that of Hudson bay, into which the waters of the Winnipeg river eventually flow. North lake, which is situated on the international boundary, some 45 miles west of lake Superior, is the headwater of the main stream. From North lake the stream flows westward, traversing many small lakes, collecting the flow of numerous tributaries, and finally discharging into Rainy lake. These upper waters in the main constitute a portion of the international boundary. Many streams, rising in lakes and muskegs, also contribute to the flow from Rainy lake. This lake has a surface of 330 square miles, and a drainage area of some 14,400 square miles. Rainy river, which is the outlet, discharges into the lake of the Woods. Thence to lake Winnipeg, the river is known as the Winnipeg. Forty miles down the river from the lake of the Woods, the flow of the English river enters that of the Winnipeg. This tributary is almost of as large dimensions as the river into which it flows, as it drains an area of 22,000 square miles, while the Winnipeg, at the lake of the Woods outlet, has a drainage area of 26,400 square miles. From the lake of the Woods to lake Winnipeg there is a total descent of 347 feet, 77 feet occurring above and 270 feet below the confluence with the English river; as this junction occurs practically at the boundary between Ontario and Manitoba, the combined flow of the two rivers, together with the greater descent as noted above, is available for power purposes in Manitoba. Of this head, a considerable portion is already being utilized by existing developments.

Estimates of the daily flow of the Winnipeg river have been compiled by the Manitoba Hydrometric Survey, based on discharge measurements secured by them, together with results of measure-

Winnipeg River—First Seven Sisters Fall

Winnipeg River—Second Seven Sisters Fall

ments supplied by Col. Ruttan, D. A. Ross and the City of Winnipeg power engineers. These estimated discharges extend over a period of eight years. For this period, a maximum flow of 53,400 second-feet and a minimum flow of 11,700 second-feet have been recorded. The high water marks along the shore indicate that floods of 100,000 second-feet have occurred, but such freshets take place only at rare intervals.

Storage on the Upper Waters

The question of storage on the upper waters of the Winnipeg river is, at present, somewhat involved, inasmuch as the regulation of the lake of the Woods is an international question, and is now before the International Joint Commission. As the lake has a tributary drainage area of 26,400 square miles and a surface area of 1,500 square miles, offering unexcelled storage facilities, it is of vital importance to the powers of the Winnipeg river that storage should be had on this lake. Partial regulation of the drainage tributary to Rainy lake is now controlled on Rainy lake by the dam of the Ontario and Minnesota Power Company at Fort Frances.

By the establishment of storage reservoirs on the English river, the flow of the latter can be regulated; and, in conjunction with storage on the Lake of the Woods basin, a very complete regulation of the flow of the Winnipeg river in Manitoba can be attained.

During the past seven years, over which records of the flow of the Winnipeg river extend, a minimum flow of 11,700 second-feet has been recorded, while the maximum flow in the same period is 53,400 second-feet, a range of only one to four, which is illustrative of the extremely low fluctuation under practically natural conditions. Yet, by an adequate system of storage, this flow can be so regulated that the minimum flow will be increased from about 12,000 second-feet to over 20,000.

DISCHARGE MEASUREMENTS OF WINNIPEG RIVER, NEAR POINT DU BOIS, MAN.

Date	Gauge Height	Discharge	Remarks
1906	Feet	Sec. ft.	
Mar. 7	160.5*	19,876	Above Pt. du Bois falls
1907			
Aug. 1	162.2*	31,047	Below diversion dam and Pinawa channel.
Aug. 2	162.2*	30,600	Barrier chute.
Oct. 31	164.2*	41,300	Otter falls.

* Gauge heights referred to lower gauge at Point du Bois.

DISCHARGE OF WINNIPEG RIVER, AT OTTER FALL, MAN.
(Drainage area, 50,300 square miles.)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1907				
January	28,170	26,000	26,960	.536
February	29,100	18,560	22,880	.455
March	19,180	15,500	17,320	.344
April	16,700	14,400	14,590	.290
May	20,420	14,400	16,290	.324
June	33,440	21,660	28,030	.558
July	34,060	30,340	32,020	.637
August	34,060	30,340	31,340	.623
September	39,020	34,680	37,140	.738
October	43,980	39,020	42,520	.846
November	42,740	42,120	42,680	.848
December	42,740	36,540	39,500	.785
Year	43,980	14,400	29,460	.586
1908				
January	40,260	35,300	36,880	.733
February	40,880	32,820	36,650	.728
March	33,440	28,480	31,380	.624
April	29,100	27,240	28,500	.566
May	37,780	29,100	32,600	.648
June	43,980	38,400	41,640	.828
July	43,980	41,500	42,980	.854
August	41,500	37,780	39,560	.786
September	39,020	33,440	35,900	.714
October	34,680	30,340	33,040	.657
November	30,340	25,380	28,400	.565
December	24,760	21,660	23,340	.464
Year	43,980	21,660	34,230	.681
1909				
January	28,480	22,280	24,770	.492
February	26,620	22,280	24,180	.481
March	22,280	16,700	18,820	.374
April	17,320	16,100	16,700	.332
May	24,140	16,100	20,300	.404
June	24,760	24,140	24,560	.488
July	25,070	23,830	24,650	.490
August	25,070	23,520	24,530	.488
September	23,520	21,660	22,290	.443
October	21,660	19,490	20,330	.404
November	21,040	19,490	20,470	.407
December	25,070	21,040	22,530	.448
Year	28,480	16,100	22,010	.438
1910				
January	27,240	24,140	25,260	.502
February	24,760	24,140	24,280	.483
March	24,140	22,900	23,830	.474
April	50,240	25,380	39,900	.793
May	53,440	50,880	52,820	1.050
June	52,160	43,360	48,690	.968

DISCHARGE OF WINNIPEG RIVER, AT OTTER FALL, MAN.—*Continued.*

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1910—*Con.*				
July	43,050	27,550	36,950	.734
August	28,480	21,970	24,700	.491
September	21,660	18,560	19,630	.390
October	18,250	15,500	17,000	.338
November	15,500	13,450	14,280	.284
December	13,450	12,400	12,920	.257
Year	53,440	12,400	28,360	.564

NOTE.—These discharges were obtained by using the gauge heights recorded at the City of Winnipeg municipal power plant, Point du Bois, together with the discharge measurements taken by Pratt & Ross for the Street Railway Co. at Otter fall.

Gauge readings were commenced at Point du Bois on January 23, 1907, and hence, the discharge given for January, 1907, applies only for 9 days, and the year period is for 343 days.

DISCHARGE OF WINNIPEG RIVER, AT SLAVE FALL, MAN.
(Drainage area, 49,700 square miles.)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1911				
January	17,140	13,350	14,820	.298
February	14,550	12,600	13,280	.267
March	13,350	11,700	12,540	.252
April	12,950	11,700	12,390	.249
May	16,860	12,780	14,770	.297
June	19,660	16,860	18,340	.369
July	25,260	19,660	22,900	.461
August	26,940	25,260	26,130	.526
September	25,820	24,140	24,810	.499
October	27,220	24,420	25,960	.522
November	25,260	20,780	22,950	.462
December	20,500	17,980	19,330	.389
Year	27,220	11,700	19,060	.384
1912				
January	22,460	17,980	20,080	.404
February	18,540	15,800	16,840	.339
March	15,550	12,300	13,820	.278
April	16,200	12,700	13,570	.273
May	27,500	16,500	22,800	.459
June	30,580	26,380	28,100	.566
July	27,220	25,820	26,380	.531
August	28,060	27,500	27,710	.558
September	30,860	27,500	29,410	.592
October	34,780	30,300	33,070	.666
November	34,500	31,700	32,610	.656
December	30,860	28,060	29,400	.592
Year	34,780	12,300	24,510	.493

DISCHARGE OF WINNIPEG RIVER, AT SLAVE FALL, MAN.—*Continued.*

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1913				
January	28,170	27,630	27,996	.563
February	28,170	22,230	26,145	.526
March	21,690	16,290	19,095	.384
April	20,610	16,290	17,847	.359
May	32,490	21,690	28,370	.571
June	33,570	31,950	32,733	.658
July	32,760	26,010	29,503	.594
August	28,710	26,550	27,695	.557
September	26,820	23,040	25,263	.508
October	22,500	14,940	18,276	.368
November	16,290	14,670	15,662	.315
December	16,290	13,050	14,722	.296
Year	33,570	13,050	23,609	.475
1914				
January	14,670	12,510	13,703	.276
February	14,440	11,700	13,233	.267
March	14,670	11,970	13,845	.279
April	15,750	13,590	14,589	.294
May	23,310	14,670	18,745	.377
June	34,650	24,930	31,480	.634
July	35,460	33,300	34,735	.698
August	33,300	29,790	31,550	.635
September	29,790	24,660	26,170	.526
October	26,550	22,500	24,805	.499
November	22,700	20,610	21,230	.428
December	21,150	18,450	19,840	.399
Year	35,460	11,700	21,995	.443
1915				
January	18,952	16,903	18,209	.366
February	18,952	16,109	17,369	.349
March	16,807	14,791	15,816	.318
April	23,406	14,543	17,939	.361
May	32,248	23,778	28,051	.564
June	33,958	30,823	32,554	.655
July	37,348	33,260	36,114	.727
August	37,198	28,388	34,950	.703
September	27,561	22,498	23,876	.480
October	22,597	19,860	20,779	.420
November	21,867	20,154	21,238	.427
December	22,398	21,369	21,976	.442
Year	37,348	14,543	24,072	.484

NOTE.—These discharges were obtained by using the gauge heights recorded at the municipal power plant, Point du Bois, together with the discharge measurements taken by the Manitoba Hydrometric Survey at Slave fall.

WINNIPEG RIVER—SPILLWAY OF POINTE DU BOIS PLANT

WINNIPEG RIVER—WINNIPEG MUNICIPAL HYDRO-ELECTRIC PLANT AT POINTE DU BOIS

MONTHLY DISCHARGE OF WINNIPEG RIVER AT WHITEDOG FALLS

(Drainage area, 27,500 square miles)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1913				
September			*12,600	.458
October	10,500	7,300	8,250	.300
November	7,800	7,150	7,550	.274
December	7,800	7,300	7,600	.276
1914				
January	7,900	7,300	7,600	.276
February	7,300	6,700	6,950	.253
March	10,500	7,300	9,400	.342
April	10,500	9,600	10,000	.363
May	15,600	10,200	11,800	.429
June	21,400	15,900	19,600	.713
July	22,200	20,800	21,600	.786
August	21,400	16,400	19,600	.713
September	15,700	13,300	13,800	.502
October	14,200	10,100	12,200	.444
November	10,300	9,600	9,800	.356
December			*9,700	.353
Year	22,200	6,700	12,700	5.530
1915				
January			*9,830	.321
February			*10,020	.364
March			*10,080	.367
April			*10,450	.380
May			*15,700	.571
June	20,583	19,517	20,029	.728
July	24,973	20,864	24,002	.873
August	24,973	18,342	22,648	.824
September	17,454	11,966	12,832	.467
October	11,853	9,749	10,304	.375
November	10,336	9,847	10,049	.365
December	10,010	9,717	9,880	.359

* Estimated.

Note.—This table gives the total combined discharges, run-off, etc., for the North and South channels at Whitedog falls.

Power Sites Developed

Point du Bois fall is utilized by the city of Winnipeg to generate power for its municipal electric plant. The natural fall was from 33 feet to 28 feet, depending upon the stage of the river, and the dams, as now constructed, increased the fall to 48 feet and 44 feet at low and high water stages, respectively, while the normal head is 45 feet. There was, originally, a stretch of slack water, eight miles long and about 3,600 acres in area above Thirty-foot and below Lamprey falls. It has been increased by the development works to 6,500 acres, and is of considerable advantage in the operation of the plant.

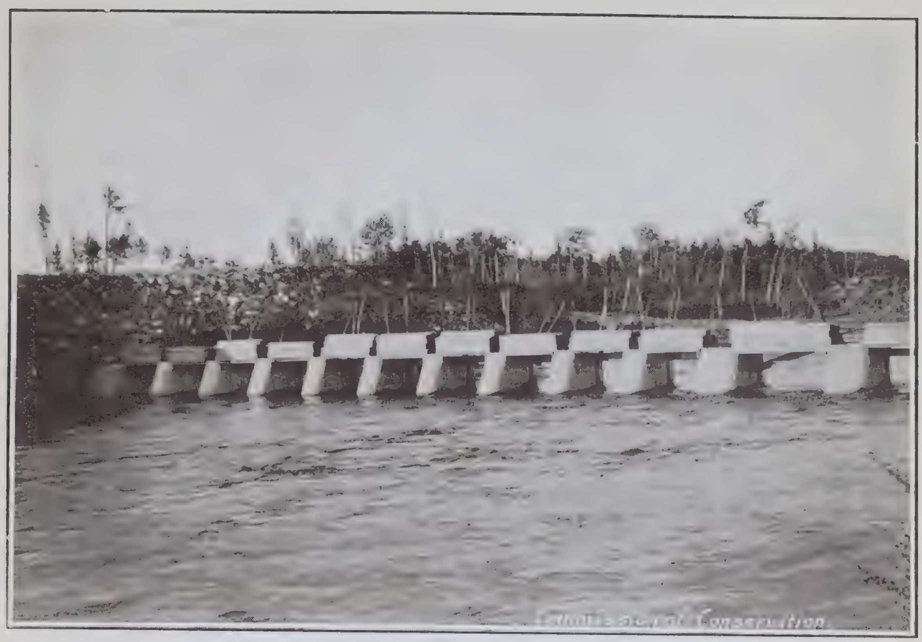
Extensions Provided for

The quantity of water to be utilized by this plant is unusual and, as a result, the power-house is constructed upon a huge scale. The building, for the accommodation of an equipment of a rated capacity of 47,000 h.p., is 252 feet long, 150 feet wide, and 100 feet high; its length is to be increased to 476 feet. The power-house was originally designed to house units of 3,000 k.w. normal rating. As a result of improvements in the design of water-wheels, it has since been possible to accommodate wheels of greater capacity in the same wheel pits. The present installation consists of five units of 3,750 k.w. and three units of 5,100 k.w. capacity, making a total of 34,050 k.w. Future extensions are planned which will accommodate eight additional units of 5,100 k.w. each. The power is generated at 6,600 volts, 60 cycles, and transformed up to 66,000 volts, with taps on the transformers permitting a range of line pressure at the generating station of from 53,000 to 72,000 volts. The transmission line is built over a private right-of-way 100 feet wide. It is 77 miles in length and traverses a varied country. The eastern section is typically Laurentian—rock, muskeg, and scattered areas of arable soil; the western section is prairie and farming country, large areas of which are closely wooded. A patrol road 12 feet wide has been built, and a considerable stretch of it has been corduroyed where the bottom is extremely unfirm. The line consists of double-circuit steel towers from 42 feet to 56 feet high, supporting two three-conductor circuits of 278,600 circular mills aluminum conductors and each circuit has a capacity of 11,250 k.w. under ordinary conditions. This capacity has now been increased by installing two synchronous motors at the receiving end of the line to overcome reactance losses. A second line with a voltage of 110,000, and ultimately raising the voltage on the existing line to this higher tension, are projects under consideration.

The terminal transformer station in Winnipeg, situated on the river front at Point Douglas, is designed to receive the entire capacity of the generating plant. The equipment of this terminal station consists of line protective and control apparatus and six transformers of 2,700 k.w. capacity, stepping the voltage down to 13,000 volts, at which voltage the electrical energy is distributed to the different sub-stations throughout the city. An extension to the present terminal station, to be built shortly, will accommodate six 5,000-k.w. transformers and is designed as the terminal for the new transmission line.

Winnipeg Electric Railway Co. Plant

The Winnipeg Electric Railway Company's power-house is constructed on the Pinawa branch of the Winnipeg river. The development work involved much rock cutting and the construction of a diversion weir, which raises the



WINNIPEG RIVER—PINAWA CHANNEL CONTROL DAM

WINNIPEG RIVER—POWER HOUSE OF THE WINNIPEG ELECTRIC RAILWAY CO.

water by about six feet at the head of the channel. The head utilized is 39 feet and the generating equipment consists of four units of 3,000 k.w. and five units of 1,500 k.w. each, giving a total capacity of 19,500 k.w.; but a greater load than this has been carried on the plant. The current is generated at 2,200 volts, 60 cycles, 3-phase, and the voltage raised to 60,000 volts by transformers, of which there are six of 1,800 k.w. and nine of 800 k.w. capacity. The transmission line is 60 miles in length and consists of one line of steel towers supporting two three-conductor lines which terminate at Winnipeg, where the voltage is stepped down in a sub-station containing transformers of the same capacity as those at the generating station. In connection with this system, there are two auxiliary steam plants in Winnipeg; one is a steam turbine plant of 9,000 k.w. capacity, generating 2,200 volts alternating current, while the other has a capacity of 2,800 k.w. for 2,200-volt alternating and 1,800 k.w. for 550-volt direct current. These auxiliary plants are used to avoid interruptions in the service during electrical storms and to supplement the hydraulic plant during short intervals at peak loads during the winter.

Government Power Proposals

Basis of Discussion on Government Power Proposals

The cost estimates for the government power proposals on the Winnipeg river refer in all cases to the capital cost of installation, and are based on both an initial and final development. The initial development is designed to utilize at each site the present minimum flow of the river, *i.e.,* 12,000 second-feet, or such portion of it as may be available at the particular site in question. The final development is designed to utilize, at each site, a regulated flow of 20,000 second-feet, or such portion of it as may be available at the site. After the diversion of sufficient water in the Pinawa channel to properly operate the plant of the Winnipeg Electric Railway Company under normal peak-load conditions, there would remain for use at Seven Sisters, in the main river, about 4,000 and 12,000 second-feet under unregulated and regulated conditions of the river, respectively. It is important to note that, it is on this basis the available power at the Seven Sisters site is discussed.

To compare the power sites on a rational and equitable basis, all the layouts and designs have been standardized in so far as possible, giving full consideration to the varying heads and to the local physical conditions at each individual site. No allowance has been made in the estimate for transmission, the costs being in all cases the capital cost for power on the low tension switchboard in the

power-house, and the power being considered as straight 24-hour service at 75 per cent efficiency, based on the flow. This forms a very conservative basis. Transmission costs are omitted from the estimates, as it is impossible to foretell the use to which the power at the various sites may be applied when developed, and a straight comparison of the sites as they stand is desired.

In all cases the dams are designed in solid concrete, with ample discharging capacity to pass the severest floods to be anticipated. The power stations have been developed on single runner, vertical turbine installations, varied for the different heads and to meet local conditions.

A continuous profile of the river, referred to mean sea level, was run at the beginning of the field work, and forms the groundwork upon which the whole survey was developed. The future needs of navigation have been recognised and, in the permanent work, provision has been made for the accommodation of future lockage facilities at the different sites. For full details see *Water Resources Paper No. 3.*

Slave Fall Site.—The proposed development at Slave fall concentrates a head of 26 feet, formed by the combination of Slave and Eight-foot falls. The dam runs along the crest of the fall, and, curving downstream, through an arc of about 90°, connects with the power station on the right bank of the river. Provision has been made for the future installation of a lock on the left bank.

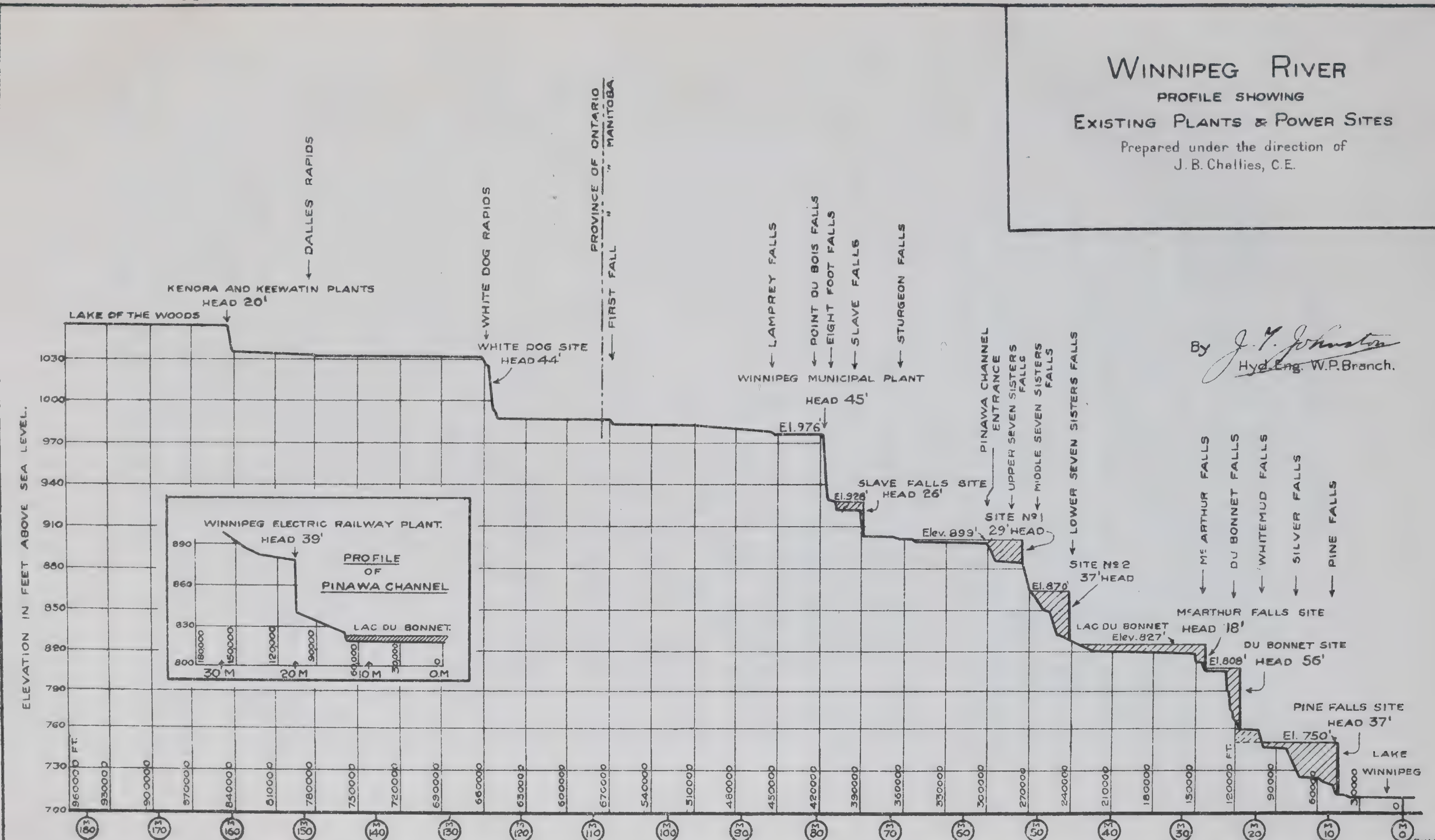
The head-water and tail-water elevations, as at prevent proposed, are 928 and 902, respectively. The initial installation, upon which the estimate is based, provides for eight 5,000-h.p. turbines, sufficient to provide for a flow of 12,000 second-feet at eight-tenths gate, with a spare machine for emergencies. On a 75 per cent efficiency, 24-hour basis, 26,600 h.p. will be available at a capital cost of $87.50 per horse-power at the low tension switchboard. The final installation provides thirteen 5,000-h.p. turbines, sufficient for a flow of 20,000 second-feet, at eight-tenths gate, with a spare machine for emergencies. On a 75 per cent efficiency, 24-hour basis, 44,400 h.p. will be available, at a cost of $77.40 per horse-power at the switchboard.

Upper Pinawa site.—This site is about three miles above the Winnipeg Electric Railway Co.'s plant on the Pinawa channel. It utilizes a hitherto inconsidered source of power in what may be termed the headrace of this Company's plant. The head to be developed here will normally average 18 feet, with the head- and tail-waters at elevations 899·5 and 881·5 respectively.

A flow of 8,000 second-feet will produce 12,300 continous twenty-four hour power at 75% efficiency. To develop this power an instal-

Winnipeg River
Profile showing Existing Plants & Power Sites

Prepared under the direction of J. B. Challies, C.E.



lation of four 4,500 h.p. turbine units has been assumed, the capital cost of the installatior being $104.05 per horse power on the low tension switchboard on a basis of twenty-four-hour power.

Upper Seven Sisters Site.—The Upper Seven Sisters site is situated about 4 miles above the lower. The tail-water, under normal conditions in the river, will be at elevation 870, *i.e.,* the proposed head-water elevation of the plant below. The head-water level has been placed at an elevation of 899, giving a normal head of 29 feet.

Since, to properly operate the existing development of the Winnipeg Electric Railway Company, an average flow of 8,000 cubic feet per second is assumed down the Pinawa channel, it will not be feasible to develop the Seven Sisters sites until the flow has been regulated to a minimum of 20,000 cubic feet per second.

Assuming the use of 12,000 second-feet, the power station provides for a complete installation of eight 6,000-h.p. units, providing a spare unit for emergencies. The estimated output on the low tension switchboard at 75 per cent efficiency is 29,600 horse-power, 24-hour service. The estimated capital cost per horse-power would be $92.00.

Lower Seven Sisters Site.—The Lower Seven Sisters site is situated about 19 miles above the McArthur site, and contemplates the development of the lower five descents of the Seven Sisters fall. The tail-water elevation has been assumed at 833, six feet being allowed for the hydraulic gradient in the river between the site and the regulated lac du Bonnet. The head-water is placed at elevation 870, the river banks permitting this raising of the water without necessitating embankments. A head of 37 feet will be available under normal conditions.

The power station provides for a complete installation of six 10,000-h.p. turbine units, sufficient to utilize a flow of 12,000 cubic feet per second. On a 24-hour and 75 per cent efficiency basis 37,900 horse-power will be available, at an estimated capital cost of $90 per horse-power, on the switchboard.

McArthur Site.—At the lower of the two McArthur falls, a head of 18 feet awaits development. The river is here divided into two channels by a large island. The general project consists of a solid concrete spillway, along the crest of the fall on the right or main channel, and a long spillway and embankment, including sluiceway provision, running diagonally across the island and connecting with the power station spanning the left channel. Provision is made on the island for the future construction of a lock.

The head-water elevation is at present fixed at 827, *i.e.,* about the highest recorded water level of lac du Bonnet. The tail-water is proposed at 809, giving a head of 18 feet.

The initial installation provides for eleven 2,500-h.p. turbines, sufficient to provide for 12,000 second-feet at eight-tenths gate, with a spare machine for emergency. On a 75 per cent efficiency, 24-hour basis, 18,400 h.p. will be available, at a capital cost of $110.40 per horse-power at the switchboard. The final installation provides for seventeen 2,500-h.p. units on a basis of a 20,000 second-feet flow, and 75 per cent efficiency, 24-hour power, *i.e.,* of 30,700 h.p. The cost per horse-power on the switchboard is $89.25. This site can be given a much more favourable aspect, when the local storage available in lac du Bonnet (whose 32 square miles form the head-waters) is taken into consideration.

Du Bonnet Site.—The proposed scheme of development at the Du Bonnet falls will ultimately concentrate there a head of 56 feet, made up of the Grand and Little du Bonnet falls and Whitemud fall. The latter will be removed by blasting out the rock-dam over which the present fall flows. The dam, consisting of embankment, spillway and sluiceway sections, leaves the left bank and crosses the river on the brink of the Little du Bonnet fall, connecting with the power station which parallels the right shore line below the pitch. Ice sluices and embankment connect the power station with the high land on the right bank. Provision is made for future lockage facilities on this bank.

The head-water elevation has been fixed at 808, with the tail-water at 762 previous to the blasting out of the Whitemud fall, and 752 subsequent thereto. This secures a head of 46 feet for the preliminary, and 56 feet for the final installations.

The initial installation is figured on seven 10,000-h.p. turbine units, utilizing 12,000 second-feet at eight-tenths gate and 46-ft. head. This, on the foregoing basis, will render available 47,100 horse-power, at a capital cost of $77.20 per horse-power, at the low tension switchboard. An intermediate installation, comprising 12 units, providing capacity for 20,000 second-feet at 46-ft. head, and producing 78,700 horse-power, has also been estimated. The cost of the power at the switchboard for this intermediate installation is $66.70 per horse-power. The final installation consists of fourteen 10,000-h.p. units for the development of 20,000 second-feet at 56-ft. head, the extra ten feet being secured by the removal of the Whitemud fall. On the above basis, 95,500 continuous horse-power will be available at a cost of $68.60 per horse-power on the switchboard.

Pine Fall Site.—The Pine fall development will concentrate the natural descent of the Pine and Silver falls, giving a head of 37 feet. The dam runs diagonally across the river from the right bank and joins directly to the power station, which forms a continuation of

WINNIPEG RIVER—SECOND MCARTHUR FALL

WINNIPEG RIVER—PINE FALL

the dam. The power station is connected with the high ground on the left bank, by sluices and embankment. Provision is made for lockage facilities on this bank.

The head-water and tail-water elevations have been placed at 750 and 713 respectively. As the tail-water is practically lake Winnipeg level, it will vary slightly from year to year with the level of the lake. The initial installation is placed at six 10,000 h.p. turbine units using 12,000 second-feet at 37 feet head. On the foregoing basis, this will render available 37,900 h.p. at a capital cost of $80.70 at the low tension switchboard. The final installation consists of ten 10,000 h.p. units for the development of 20,000 second-feet, rendering available 63,100 h.p. at a cost of $69.80 per horse power.

Summary of the Power Possibilities of the Winnipeg River

The developed and undeveloped powers of the Winnipeg river, under regulated and under unregulated conditions, are tabulated on page 26. The undeveloped power is considered on a 75 per cent efficiency, 24-hour basis, and the capital cost per horse-power is given in terms of this power, estimated to the switchboard in the power-house.

Future Economic Value of Winnipeg River Powers

With regard to the future economic value of the powers of the Winnipeg river, the following is quoted from a report made to the Water Power Branch, Dept. of Interior, in September, 1911, by Mr. J. R. Freeman, one of the consulting engineers retained by the department for advice in connection with water-power matters. Mr. Freeman says:—

> *Economy and Conservation.*—While water-power opportunities on the Winnipeg river may have, a very few years ago, appeared so far beyond possible use that ordinary economies were unnecessary, it is, I believe, plain to-day beyond serious question that all the remaining opportunities for power should be carefully conserved, and only developed under such conditions as will not necessitate any great waste or the impairment of remaining opportunities.
>
> Sundry remarkable electro-chemical processes have been very recently invented, which promise to be of great future benefit to agriculture and other arts. Fertilizer for farmers' use is now being successfully made by electricity from the nitrogen of the air, and great water-powers in Norway are now being developed for these purposes, in addition to those already in use, and recent developments have also been made of similar processes not far from the southern boundary of Canada.
>
> The great uses of hydro-electric power at Niagara Falls and at Sault Ste. Marie, for making aluminum, carbide for gas lighting, bleaching powders, caustic soda and sundry other important pro-

ducts, were unknown only a few years ago. Indeed, it may be said that every one of the electro-chemical plants now situated at Niagara Falls has been invented since the first of the large hydro-electric power stations was built at that point. It is idle to say that the era of important electro-chemical invention is yet more than begun, and with the many able investigators now earnestly working on these lines in many parts of the world, great additional discoveries and commercial developments in the application of cheap electric power are almost certain to come, particularly in metallurgy or the reduction of ores.

The Winnipeg Market now Fully Supplied.—The city of Winnipeg will soon have all the power that it needs for public service, corporation and for any conceivable manufacturing purposes likely to locate in or near the city for perhaps a score of years to come, from the railway company's plant already in use and to-day understood to be delivering about 22,000 horse-power, and from the new municipal hydro-electric power plant at Point du Bois, now (1911) nearing completion, with a first installation of 26,000 horse-power and with works planned to be extended to more than three times that capacity. Thus these two plants will be capable of delivering to Winnipeg more than 100,000 horse-power of 24-hour electrical energy, a quantity which can be best appreciated by a statement that this is far greater than the total water-power at Lowell, Lawrence, Manchester and Holyoke, Mass., combined.

A Possible Field for Use.—The best use that I can foresee for the vast water-powers upon the Winnipeg river now remaining untouched is as the basis for founding three or four new industrial cities based upon electro-chemical industry, very much as water-power was the basis for creating, years ago, the cities of Lowell, Lawrence, Manchester, Holyoke, Bellows Falls, and, as in recent years, it has brought together hundreds of new homes at Niagara Falls, Shawinigan Falls and at the Sault.

We cannot to-day say what the line of manufacture may be, for the electro-chemical arts are still in a state of ferment and creation. It has already been demonstrated that, by electric smelting, steel for the manufacture of tools can be made having a quality and value difficult to obtain otherwise. Fertilizer in the form of artificial saltpetre is being produced commercially in large quantities under German processes, while carbide, carborundum, aluminum and numerous other useful products, are being made by electro-chemical means in great quantity at Niagara and elsewhere, and sooner or later the time will come when fertilizer will not be scorned by the farmers of the Canadian Northwest. There is promise of new metallurgical processes for which cheap electricity is a necessity and the price per pound of several of those products is such that they could stand a considerable cost of freighting to their markets, and such that a power capable of being developed in so vast quantity at one point, and at so low a cost per horse-power as appears practicable at three of the sites along the Winnipeg river, will surely be very attractive.

These New Industries Must Build Close to the Waterfall.—These electro-chemical processes, when carried on in a large commercial way, demand that the work be done close to the point where the power is generated, for two reasons:—first, because although the air-saltpetre process uses alternating current, most electro-chemical processes require the direct current at low voltage, which cannot be transmitted to great distances with anything like the facility of alternating current; and, second, because, in order to attract those processes, it is necessary that the cost per horse-power be the very lowest, and not overloaded by the cost of long transmission lines or the percentage of power necessarily lost in such transmission.

Wherever a new industrial centre, with some hundreds of homes, can be established in the wilderness within a hundred miles of Winnipeg, it will add to Winnipeg's prosperity in a degree but little less than if situated within its borders, and will add to the prosperity of the province by the new opportunities that it brings for employment, the diversity that it adds to its business interests, and by the money that it will put into circulation. It is plain that many of the recent power developments made in various parts of America, from which the power is transmitted long distances, to displace steam power in populous centres, results in putting a much larger number of men out of work than it sets at work. Such a development is of less benefit to the country than the early water-power developments, which were used locally in erecting the cities already named, in building hundreds of new homes, and in setting thousands of men working at new opportunities.

TABLE OF DEVELOPED AND UNDEVELOPED POWERS ON THE WINNIPEG RIVER IN MANITOBA

Plant or site	Head-water, elevation	Tail-water, elevation	Head	Turbine capacity at full gate at Govt. proposals		H.P. at 75% efficiency on a 24 hr. basis		H.P. developed	Capital cost per h.p. on switchboard		Remarks
				12,000 sec.-ft.	20,000 sec.-ft.	12,000 sec.-ft.	20,000 sec.-ft.		12,000 sec.-ft.	20,000 sec.-ft.	
									$ cts.	$ cts.	
Winnipeg municipal plant	975.7	930.7	45			46,100	76,800	25,000			47,000 h.p. installed.
Slave Falls site	928	902	26	40,000	65,000	26,600	44,400		37.50	77.40	
Winnipeg Electric Railway Co. plant	879.4	840.4	39					28,200			On Pinawa channel. 34,000 h.p. installed.
Upper Pinawa	899.5	881.5	18	18,000	18,000	12,300	12,300		104.05	104.05	On Pinawa channel.
Upper Seven Sisters site	899	870	29		48,000	9,900	29,600			92.00	Less discharge down Pinawa channel.
Lower Seven Sisters site	870	833	37		60,000	12,600	37,900			90.00	Less discharge down Pinawa channel.
McArthur site	827	809	18	27,500	42,500	18,400	30,700		110.40	89.25	
Du Bonnet site.............		762	46	70,000	120,000	47,100	78,700		77.20	66.70	Preliminary head.
	808	752	56		140,000	57,300	95,500			68.60	Final head.
Pine site	750	713	37	60,000	100,000	37,900	63,100		80.70	69.80	

Total power with unregulated river (12,000 second-feet min. flow) is 249,300 horse-power.
Total power with regulated river (20,000 second-feet reg. flow) is 418,500 horse-power.
Total power developed to date, 53,200 horse-power.

Whitemouth River

The Whitemouth river rises in Whitemouth lake, in the south-easterly portion of Manitoba, and flows northerly to the point where it joins the Winnipeg river, just below the Upper Seven Sisters rapids.

The drainage area of the river is 1,566 square miles. The lower portion of this area is narrow and mostly cultivated, while the upper portion expands and forms part of the Julius muskeg.

The bed of the river consists almost entirely of boulder-clay, with occasional outcrops of rock in the lower reaches, crossing the river at right angles. These rock outcrops do not appear above bed elevation except in the vicinity of the Whitemouth falls, at the mouth of the river. The banks throughout, with the above exception, are composed of a sandy clay, and rise to a height of approximately 50 feet. In some localities, this height is reached by a steep slope from the water's edge, while, in others, the slope is more gradual, extending for a distance of 400 feet.

Timber and Vegetation

For a distance of about two miles from the mouth of the river there is much valuable standing timber, including oak, spruce and poplar, but, as the course is followed southward, it is found that the land has been cleared, partly by fire and partly by the settlers in breaking up the land for farming purposes, so that only occasional clumps of poplar, ash and elm are encountered. Throughout the upper reaches of the river the land is mostly covered with small tamarack, spruce and scrub.

Precipitation.—From the meteorological reports at Oakbank, west of the drainage basin, and at Kenora, to the east, extending over a period of twenty-two and nine years, respectively, it is found that the mean annual precipitation for the section of the country covered by the drainage area is approximately 21 inches.

A reconnaissance survey of the river, from the mouth up to the Canadian Pacific Railway crossing at the town of Whitemouth, was made by the Manitoba Hydrographic Survey in June, 1913.

Power Possibilities

The development of power on this river is possible at two sites.

Site No. 1.—Part of this descent could be concentrated at the fall at the mouth of the river and a head of 20 feet obtained.

Site No. 2.—About three miles below the town of Whitemouth a head of approximately 20 feet is obtainable, the high banks enabling successful development without flooding any considerable area of valuable land.

A minimum mean monthly flow of 45 second-feet for the open water season occurred in 1915. The estimated power, assuming an efficiency of 80 per cent, with this flow would be 82 h.p. at each of the two sites during the open water season.

MONTHLY DISCHARGE OF WHITEMOUTH RIVER, AT WHITEMOUTH, MAN.

(Drainage area, 1,400 square miles)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1912				
May (29-31)	2,151		2,000*	1.43
June	1,829	392	961	.69
July	1,518	240	1,000	.71
August	1,262	473	757	.54
September	2,375	1,356	1,789	1.28
October	2,130	993	1,675	1.20
November	1,570		900*	.64
December			100*	.07
1913				
January			25*	.02
February			25*	.02
March			25*	.02
April (8-30)	3,148	1,202	1,600*	1.14
May	1,279	607	899	.64
June	818	158	436	.31
July	1,234	186	626	.45
August	914	72	423	.30
September	479	133	229	.16
October	138		100*	.07
1914				
January			20*	.014
February			20*	.014
March			20*	.014
April			300*	.214
May	1,393	483	903	.645
June	2,491	244	1,152	.823
July	2,147	193	733	.523
August	259	22	95	.068
September	286	86	150	.107
October	1,172	130	630	.450
November			250*	.179
December			60*	.043

* Estimated.

WINNIPEG RIVER—LITTLE DU BONNET FALL

WINNIPEG RIVER—GRAND DU BONNET FALL (SECOND PITCH)

MONTHLY DISCHARGE OF WHITEMOUTH RIVER, AT WHITEMOUTH, MAN.—*Continued*

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1915				
January			18*	.013
February			10*	.007
March			10*	.007
April			450*	.321
May	1,720	463	1,110	.793
June	1,000	308	697	.498
July	967	58	447	.319
August	240	26	83	.059
September	177	25	45	.032
October	350	193	267	.191
November			210*	.150
December			100*	.071

* Estimated.

CHAPTER II

Red and Assiniboine Rivers*

METERING STATIONS ESTABLISHED BY THE MANITOBA HYDROGRAPHIC SURVEY

Name of river	Situation	When established	Remarks
Red	Emerson	May, 1912	
Roseau	Dominion City	May, 1912	Abandoned in 1913
Roseau	Baskerville	April, 1913	
Assiniboine	St. James	May, 1912	Abandoned in 1913
Assiniboine	Headingly	Spring of 1913	
Assiniboine	Brandon	July, 1912	
Assiniboine	Millwood	Oct., 1912	
Souris	Wawanesa	Oct., 1912	
Minnedosa	Riverdale	Jan., 1913	

Red River

The Red river rises in the state of Minnesota. It flows, first, in a southerly direction for a distance of 60 miles, then west for 100 miles to Breckenridge, on the boundary line between Minnesota and North Dakota. Thence to the international boundary the river forms the dividing line between these two states. Continuing its course through Manitoba, it falls into lake Winnipeg at its southern extremity. From Breckenridge to Winnipeg, a distance of 250 miles, the general direction of the river is almost directly north, and its course does not vary from a straight line by more than five miles. Below Winnipeg it flows in a north-easterly direction.

An idea of the extremely winding nature of the river can be gathered from the fact that, in its course from Breckenridge to Winnipeg, though the general course does not vary to any great extent from a straight line, the length of the actual river channel is more than double the distance by direct line. This characteristic is common throughout its length.

Large Area of River Basin

The drainage basin of the river includes an area of 116,347 square miles, of which 42,547 are in Minnesota and Dakota, 50,500 in Saskatchewan, and 23,300 in Manitoba. The drainage basin of its largest tributary, the Assiniboine, forms a considerable portion of this area.

*The data for this chapter were contributed by the Water Power branch of the Department of the Interior, with the exception of the sections dealing with Qu'Appelle river, Birdtail and Moose Jaw creeks and portions of Souris and Minnedosa rivers.

The principal tributaries entering the Red in Manitoba are the Roseau, the Rat and the Seine, from the east, and the Assiniboine and Morris rivers from the west. The Pembina river, though the greater part of its drainage area lies in southern Manitoba, joins the Red south of the international boundary.

The entire basin is practically a level plain, varying in width from 50 to 200 miles, and having a length of over 300 miles of water. There is a gentle slope, from the sides of the valley to the centre, of about the same gradient as from the headwaters to the mouth of the river, namely, approximately one foot per mile. Down the centre of the valley, the river has cut a sharp, winding channel, from 20 to 50 feet below the level of the plains on either side. The banks of this channel are composed of a gravelly clay, and, though no rock outcrops show in the course of the river, the bed near the mouth is underlain by a stratum of rock at a depth varying from 10 to 20 feet.

Throughout the Red River valley in Manitoba, there is very little standing timber except in the extreme easterly portion. Along the course of the river occasional clumps of elm and ash occur, though not of sufficient extent to warrant extensive lumbering operations.

The district is mostly prairie, and, being situated along the line of first immigration into Manitoba, is naturally one of the oldest settled portions of the province. The larger percentage of the land is settled and is cultivated continuously, being of a very productive nature.

Navigation during Open Months

The river is navigable for boats of light draught from the mouth up to Grand Forks, N. Dak. Prior to the construction of the railways, it was used extensively during the open season for freight and passenger service. Since the coming of the railways, however, river traffic, unable to compete with the faster mode of transportation, has gradually dwindled.

There has been considerable revival of river travel in the lower reaches since the construction by the Dominion Government of the St. Andrews dam and lock near the mouth of the river. This dam, which raises the level at Winnipeg by about eight feet, ensures the boats from lake Winnipeg ample water up to the city of Winnipeg.

In its course through Manitoba, the first town passed is Emerson, situated at the international boundary, and, from this point to Winnipeg, there are several smaller towns. They are, in some instances, removed a mile from the river, being situated on the Canadian Northern railway, which closely parallels the river. Between Winnipeg and the mouth, the largest town is Selkirk, about 22 miles below the city, but there are small settlements scattered throughout almost the entire distance.

Precipitation.—From records in central Minnesota, covering a period of thirty years, it is found that the mean annual precipitation at the headwaters of the river is 24 inches, and the records at Winnipeg, covering a period of 40 years, give the mean annual precipitation at that point as 21 inches. In the western portion of the drainage area, the precipitation is noticeably less than that given above, and does not average more than 17 inches.

The rise and fall of the Red river is, as a rule, gradual, except during the spring floods. These freshets are caused by the release of the water—held in the form of snow and ice—in the warmer southern reaches of the river, before the break-up in the colder sections near the mouth. As it reaches the section of the river where the break-up has not yet taken place, this water, unable to obtain easy egress, backs up and frequently rises 20 to 30 feet above normal level.

Water-Power Possibilities

In Manitoba the only feasible power development is situated at Lockport, where the construction of the dam at St. Andrews rapids has concentrated a head of approximately 15 feet. As the shutters of this dam are raised during the winter and during freshets, any development at this point would necessarily be for operation only during the period when the dam is held as an aid to navigation, usually between May and October.

The estimated power available at this site, based on an 80 per cent efficiency, assuming a head of 15 feet, and an estimated low flow of 2,000 second-feet would be 2,730 horse-power. Calculated from the information at hand the lowest mean monthly flow of the river where it enters the province, and of the tributaries entering in its course between Emerson and Lockport, is 2,000 second-feet. This discharge is estimated only for six months, ending October 31, 1913, 1914 and 1915, and is subject to revision.

MONTHLY DISCHARGE OF RED RIVER, NEAR EMERSON, MAN.

(Drainage area, 34,600 square miles)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1912				
May	2,938	1,500	2,350*	.068
June	2,650	1,340	1,729	.050
July	1,910	969	1,126	.033
August	1,715	841	1,030	.030
September	2,418	841	1,117	.032
October	3,565	1,473	2,270	.066
November	1,542	1,201	1,400	.046
December			700*	.020

MONTHLY DISCHARGE OF RED RIVER, NEAR EMERSON, MAN.—*Continued*

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1913				
January			500*	.015
February			300*	.009
March			300*	.009
April	26,020	1,665	13,150	.380
May	5,230	2,276	3,195	.092
June	2,248	1,243	1,731	.050
July	1,765	969	1,308	.038
August	1,209	782	935	.027
September	1,615	782	1,139	.033
October	1,473	819	1,160	.035
1914				
January	761	429	670	.019
February	736	600	675	.019
March			600*	.017
April			2,000*	.058
May	4,800	2,420	3,250	.094
June	7,250	2,490	4,400	.128
July	5,250	1,900	3,475	.101
August	1,830	1,180	1,380	.040
September	1,510	1,190	1,330	.039
October	1,650	1,200	1,380	.040
November			1,400*	.040
December			800*	.023
Year	7,250	429	1,780	.618
1915				
January	969	899	938	.027
February	903	848	868	.025
March	1,500	883	992	.029
April	10,058	1,600	5,097	.147
May	5,504	2,613	3,744	.108
June	10,002	2,420	5,020	.145
July	20,121	5,296	13,149	.380
August	5,008	2,004	2,947	.085
September	2,004	1,642	1,798	.052
October	1,885	1,680	1,818	.053
November	1,815	1,447	1,638	.047
December	1,609	1,545	1,588	.046
Year	20,121	848	3,316	.096

* Estimated.

The following is a summary of observations on the flow of the Red river, taken at Grand Forks, by the U. S. Geological Survey:

MONTHLY DISCHARGE OF RED RIVER, AT GRAND FORKS, N. DAK.
(Drainage area, 25,000 square miles)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1907				
January			1,400*	0.056
February			1,090*	.044
March			3,070*	.123
April	30,300	6,310	16,700	.668
May	6,300	3,550	4,550	.182
June	10,600	3,080	6,000	.240
July	4,630	2,310	3,290	.132
August	2,280	1,540	2,000	.080
September	3,170	1,370	1,950	.078
October	2,680	1,560	1,970	.079
November	1,700		1,440	.058
December			1,200*	.048
Year	30,300		3,560	.149
1908				
January			890*	.036
February			800*	.032
March			960*	.078
April	20,500	4,400	9,850	.394
May	9,520	3,390	5,790	.232
June	8,680	5,360	7,140	.286
July	5,150	2,330	3,290	.132
August	2,530	1,660	1,970	.079
September	3,550	1,330	1,760	.070
October	1,610	1,270	1,440	.058
November	1,390	1,200	1,250	.050
December			830*	.033
Year	20,500		3,080	.123
1909				
January			703*	.028
February			564*	.023
March			925*	.037
April	5,180	2,480	4,340	.174
May	3,690	2,780	3,090	.124
June	5,050	2,380	3,110	.124
July	9,260	2,150	3,780	.151
August	8,040	4,320	5,590	.224
September	4,920	2,530	3,210	.128
October	2,480	1,970	2,230	.089
November	2,430	1,040	1,900	.076
December			2,430*	.097
Year	9,260		2,660	.106
1910				
January			1,520*	.061
February			1,300*	.052
March	18,500		8,420	.336
April	10,800	5,020	7,840	.314
May	8,440	2,750	4,340	.174
June	2,560	1,170	1,950	.078
July	1,140	703	860	.034
August	691	373	490	.020
September	562	354	426	.017
October	492	343	413	.017
November	470	280	395	.016
December			310*	.012
Year	18,500		2,360	.094

DISCHARGE OF RED RIVER, AT GRAND FORKS, N. DAK.—*Continued*

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1911				
January			210*	0.0084
February			185*	.0074
March			760*	.030
April	2,720		1,880	.075
May	2,380	1,120	1,500	.060
June	3,500	1,050	1,760	.070
July	1,060	318	578	.023
August	464	331	392	.016
September	454	347	391	.016
October	639	271	463	.018
November			370*	.015
December			340*	.014
Year	3,500		736	.029
1912				
January			140	.006
February			110	.004
March			300	.012
April	4,710	940	2,470	.099
May	2,360	940	1,670	.067
June	1,520	740	1,130	.045
July	837	592	698	.028
August	837	426	559	.022
September	2,630	385	755	.030
October	2,520	864	1,300	.052
November	1,150		812	.032
December			422	.017
Year	4,710		863	.035
1913				
January			318	.013
February			233	.009
March			282	.011
April			7,060	.282
May	2,590	1,380	1,820	.073
June	1,590	890	1,190	.048
July	1,720	686	1,030	.041
August	1,110	560	760	.030
September	1,670	560	1,030	.041
October	1,420	654	1,050	.042
November	1,380	890	1,140	.046
December			793	.032
1914				
January			509	.020
February			428	.017
March			911	.036
April			2,990	.120
May	4,750	1,830	2,560	.102
June	9,200	1,780	4,820	.193
July	6,450	1,380	2,840	.114
August	1,300	862	1,090	.044
September	1,630	890	1,180	.047

* Estimated from a few discharge measurements.

Roseau River

The Roseau river is the largest tributary entering the Red from the east, in its course through Manitoba. It has its headwaters in the low lands lying to the west of lake of the Woods. About half its total length lies south of the international boundary and it joins the Red river approximately ten miles north of same. The general direction of the river is northwest, and its course is very tortuous.

The drainage basin of the river includes an area of 1,987 square miles—1,097 in Minnesota and 890 in Manitoba. The major portion of this area is flat land; that in the upper reaches is so flat that cultivation is impossible without artificial drainage. In connection with this work, 40 miles of the upper section of the river in Minnesota has been straightened and widened to eighty feet, and, for a considerable distance, the land on either side is drained by ditches spaced one mile apart. In the lower reaches of the river, the effect of this drainage is shown by the rapid rise apparent during times of heavy rainfall.

The course of the river, from source to mouth, lies through level country, with no perceptible valley of any extent. The banks cut sharply down from the prairie level to the bed of the stream. The composition of these banks is stated to be invariably a heavy clay, which also forms the bed of the river. The height of the banks varies from 10 to 12 feet.

A large percentage of the land throughout the drainage basin of the river in the province of Manitoba is cultivated, and the little standing timber consists mostly of small elm, ash and oak, very little of which is large enough to have commercial value except as firewood.

In the course of the river through Manitoba, three settlements are met with. The first, situated close to the headwaters, is the village of Sprague, on the Ridgeville branch of the Canadian Northern railway. The second is Stuartburn, on the same line, and the third Dominion City, at the crossing of the Canadian Pacific railway, Emerson branch.

Precipitation.—From records of northern Minnesota, covering a period of 30 years, and at Oakbank, to the north of the drainage area, covering a period of 22 years, it is found that the mean annual precipitation in the watershed of the Roseau is 22 inches.

Power Possibilities

No surveys for the purpose of locating power sites have been made on this river, and information as to the possibility of concentrating the natural fall at points throughout its course is very meagre. Local authority reports that,

in the neighbourhood of Dominion City, there is a possible development of 15-foot head, but this has not been investigated.

Between Sprague, near the headwaters, and Dominion City, a distance of about 200 miles by river, it descends 295 feet, or about 1.5 feet per mile.

Should any development be made on this river, and a continuous supply of power be required, it would necessitate the installation of an auxiliary steam plant for use during periods of extreme low flow, as the absence of storage areas in the upper reaches of the river probably debars economic storage regulation.

As during certain winter months, the flow is entirely cut off, estimates of power can only be made for the period from May to October. Assuming a low mean monthly flow of 24 second-feet during this period and an efficiency of 80 per cent, every 10 feet of head could produce 22 h.p.

DISCHARGE OF ROSEAU RIVER, AT DOMINION CITY, MAN.

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1912				
May (20-31)	468	371	416*	.18
June	410	45	200	.09
July	98	30	60	.03
August	132	83	113	.05
September	527	103	186	.08
October	1,354	577	1,059	.46
November	1,248	369	795	.35
December			80*	.03

* Estimated.

DISCHARGE OF ROSEAU RIVER, AT BASKERVILLE BRIDGE, MAN.
(Drainage area, 1,900 square miles)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1913				
January			20*	.01
February			0*	
March			0*	
April			300*	.16
May	1,517	272	673	.35
June	274	129	227	.12
July	254	136	174	.09
August	126	31	68	.04
September	97	33	56	.03
October			40*	.02

DISCHARGE OF ROSEAU RIVER, AT BASKERVILLE BRIDGE, MAN. —*Continued*

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1914				
January			6*	.003
February			5*	.003
March		4	25*	.013
April			570	.300
May	863	406	626	.329
June	748	391	600	.316
July	414	205	298	.157
August			75*	.040
1915				
May			775*	.428
June	927	417	678	.375
July	1,084	477	840	.464
August	454	51	172	.095
September	44	3	24	.013
October	65	35	52	.029
November			60*	.033
December			30*	.017

* Estimated.

Pembina River

The Pembina river rises on the northeasterly slopes of Turtle mountain and flows easterly to a point fifty miles above its mouth, where it turns southward, crossing the international boundary, then, turning again to the east, flows into the Red river about five miles south of Emerson.

The basin of the river includes an area of 4,180 square miles, 1,440 in Dakota, the remainder, 2,740, in southern Manitoba. In the upper reaches of its basin, there are numerous small lakes and sloughs which furnish most of the drainage. One notable feature of its watershed is the fact that practically all the drainage enters it from the south. The tributaries entering from the north have very little flow, except in the early spring or times of excessive rains.

The principal tributaries are the Whitemud river, Long river, Beaver creek and Snowflake creek, all flowing from the south.

Nature of Bed and Banks

The lower 40 miles of the course of the river lie in flat country, typical of the Red River valley. The banks of the stream cut sharply down from the level of the prairie to a depth of from 20 to 40 feet. The banks in this section are usually of sandy clay, which also constitutes the bed of the river. After the above distance is traversed, the banks become bolder, and rise to a height varying from 175 feet to 450 feet. The nature

of the soil in the valley also changes, being much more sandy; the flood plain and bed of the river are composed of sandy gravel strewn with boulders.

The average width of the river is approximately 90 feet but, in the middle reaches, it widens in several places, forming lakes varying in width from one-half mile to a mile and a half. The more important of these expansions are Swan lake and Rock lake, six and nine miles long, respectively.

The Pembina is not navigable, but, flowing through a well settled country, it is easily accessible from good roads, and also from railways, which cross it at many points.

Precipitation.—The mean annual precipitation at the mouth of the river is 20 inches but, at the headwaters, the yearly average is only 14 inches. This small precipitation has a decided effect on the flow, since it is in this locality that most of the drainage enters the river, and, in times of drought, the discharge dwindles to an extremely small volume.

Discharge Measurements.—For some years the United States Geological Survey has gauged the flow at Neche, North Dakota. From the report of these gaugings, it will be seen that there is a large variation in the flow of the river; the mean monthly discharge ranges from the low flow of one second-foot during the month of September, 1911, to a high flow of 3,870 in May, 1904.

Water-Power Possibilities

There is no information available respecting any surveys having been made on the river for the purpose of locating water-power sites, but the nature of the valley, and the natural fall of the river, indicate the possibility of development. The descent of the river, from the base of Turtle mountain to the point where the valley opens out into that of the Red river, is 700 feet, or approximately three feet per mile.

As the low-water flow is extremely small, any power development depending upon the natural flow would be subject to serious interference through lack of water for a considerable portion of the year.

A certain amount of storage could be obtained on the lakes in the course of the river, and also on Pelican lake, which is about two miles distant from the river channel. Whether this storage would be sufficient to carry any development over the period of low flow is very doubtful.

MONTHLY DISCHARGE OF PEMBINA RIVER, AT NECHE, N. DAK.
(Drainage area, 2,940 square miles)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1903				
May			202	
June	198	110	149	
July	110	35	60	
August			35	
October			42	
November			42	
1904				
April	3,580	217	1,920	0.653
May	3,870	1,420	2,640	.898
June	2,530	926	1,690	.575
July	2,690	399	839	.285
August	420	315	385	.131
September	315	236	302	.103
October	275	217	235	.080
November	217	131	183	.062
1905				
March 23-31	672	530	606	.216
April	1,372	311	549	.196
May	1,180	218	447	.160
June	1,180	279	485	.173
July	399	119	206	.074
August	137	60	97	.035
September	119	65	93.9	.034
October	150	70	119	.042
November 1-26	137	91	116	.041
1906				
April	1,220	193	479	0.163
May	231	175	193	.066
June	340	193	271	.092
July	270	119	175	.060
August	143	119	131	.045
September	166	136	147	.050
October	150	136	144	.049
November	136	82	111	.038
1907				
April 21-30			860	.293
May	2,190	826	1,600	.544
June	805	263	507	.172
July	272	76	156	.053
August	80	36	54.3	.014
September	47	23	34.8	.012
October	66	36	55.2	.019
November			38.0	.013
December			19.0	.006
1908				
January			6	.002
February			3	.001
March			3	.001
April	927		375	.128
May	591	310	474	.161
June	486	136	224	.076
July	136	36	87.8	.030
August	66	36	52.1	.018
September	78	55	60.9	.021
October 1-10	55	45	49	.017

NOTE.—Obtained from records of Water Resources Branch, U. S. Geological Survey.

MONTHLY DISCHARGE OF PEMBINA RIVER, AT NECHE, N. DAK.—*Continued*

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1909				
June	654	268	427	.145
July	164	73	113	.038
August	100	22	48.3	.016
September	32	22	27.7	.0094
October	73	32	45.9	.016
November	67	38	51.9	.018
1910				
March	685	115	349	.118
April	250	147	166	.056
May	164	86	120	.041
June	100	7	60.4	.020
July	100	10	34.9	.012
August	10	3	6.87	.0023
September	7	3	3.93	.0013
October	10	3	6.39	.0022
1911				
March 23-31	900*	450*	641*	0.218
April	420	181	294	.100
May	520	133	231	.079
June	198	118	154	.052
July	110*	15*	49.2*	.017
August	35	11	24.1	.0082
September	17	1	5.7	.0019
October	35	2	19.6	.0067
1912				
March 27-31	100	80	94.0	.032
April	195	130	158	.054
May	330	130	174	.059
June	288	71	148	.050
July	870	53	129	.044
August	274	10	85.5	.029
September	330	10	181	.062
October	221	150	191	.065
November 1-23	300	150	202	.069
1913				
April	3,850		1,670	.57
May	850	330	529	.18
June	330	49	191	.065
July	159	66	106	.036
August	84	66	69.5	.024
September	66	57	61.8	.021
October	75	49	63.6	.022
1914				
April			254	.086
May	241	160	195	.066
June	160	87	126	.043
July	87	22	48.4	.016
August	22	6	13.4	.005
September	22	6	12.9	.004

* Estimated.

Assiniboine River

The Assiniboine river rises in Saskatchewan, on the southeasterly slopes of Nut mountain, adjacent to the headwaters of the Red Deer river. Thence, it flows southwesterly until it crosses the boundary between Saskatchewan and Manitoba, where it turns and flows southward until approximately in the latitude of Brandon; thence, it flows easterly to its confluence with the Red river, in the city of Winnipeg.

River Basin and Banks

Its drainage basin includes an area of 59,550 square miles. Of this area, approximately 8,800 square miles lie in North Dakota, 37,700 in Saskatchewan and 13,050 in Manitoba. Its principal tributaries are the Qu'Appelle, Souris, Shell and Minnedosa (Little Saskatchewan).

As the basin is confined between the watersheds of the Red river and of lake Manitoba, the drainage entering the river in the lower 100 miles of its course is very small. Above Brandon, there is a large increase in drainage, and, in its upper course, it is fed by springs and by streams draining the numerous small lakes of the upper basin.

Where it crosses the Manitoba-Saskatchewan boundary it flows in a narrow valley, with banks rising sharply to a height of 250 feet on the east side, but with a more gradual rise on the west to approximately the same elevation.

The high banks of the valley are characteristic of the river until it has reached a point considerably below the confluence of the Souris river. Thence to the mouth it flows through level prairie with sharply cut banks, rising directly from the water's edge to a height varying from 3 or 4 feet to 25 feet.

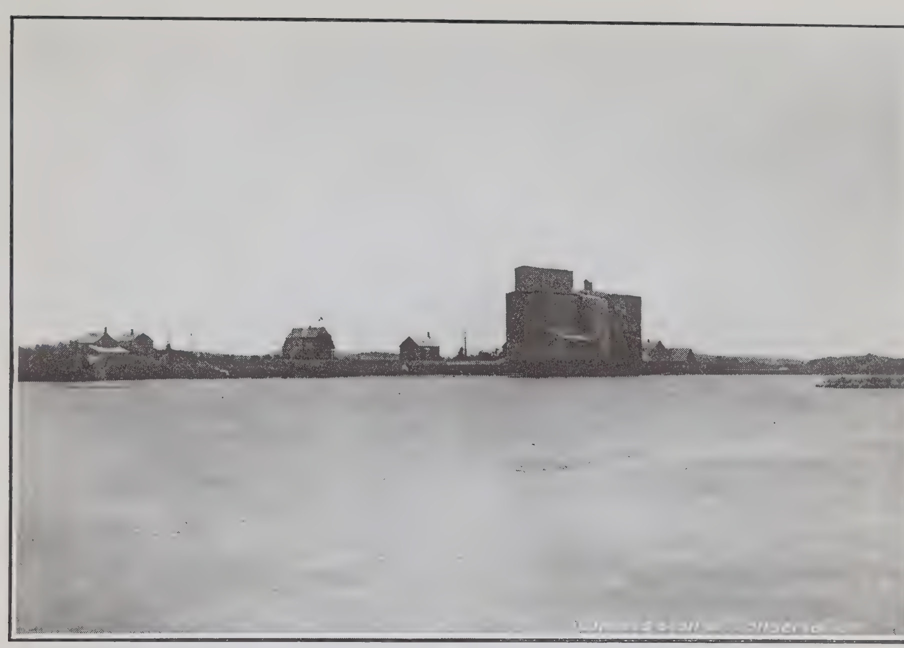
There is a great variation in the width of the valley, which, in several districts, widens sufficiently to permit extensive farming operations on the flats on either side of the river. The soil of these flats, though rich, is in constant danger of flooding from spring freshets.

The bed of the river, where it enters Manitoba, is approximately 150 feet wide, with a maximum of 250 feet.

In the upper reaches, the bed is mostly of a sandy or gravelly nature, strewn with large boulders, but, near the mouth, the banks and bed are composed largely of a sandy clay and boulders, with an underlying stratum of blue clay at a depth of from five to ten feet.

Purely Agricultural Country

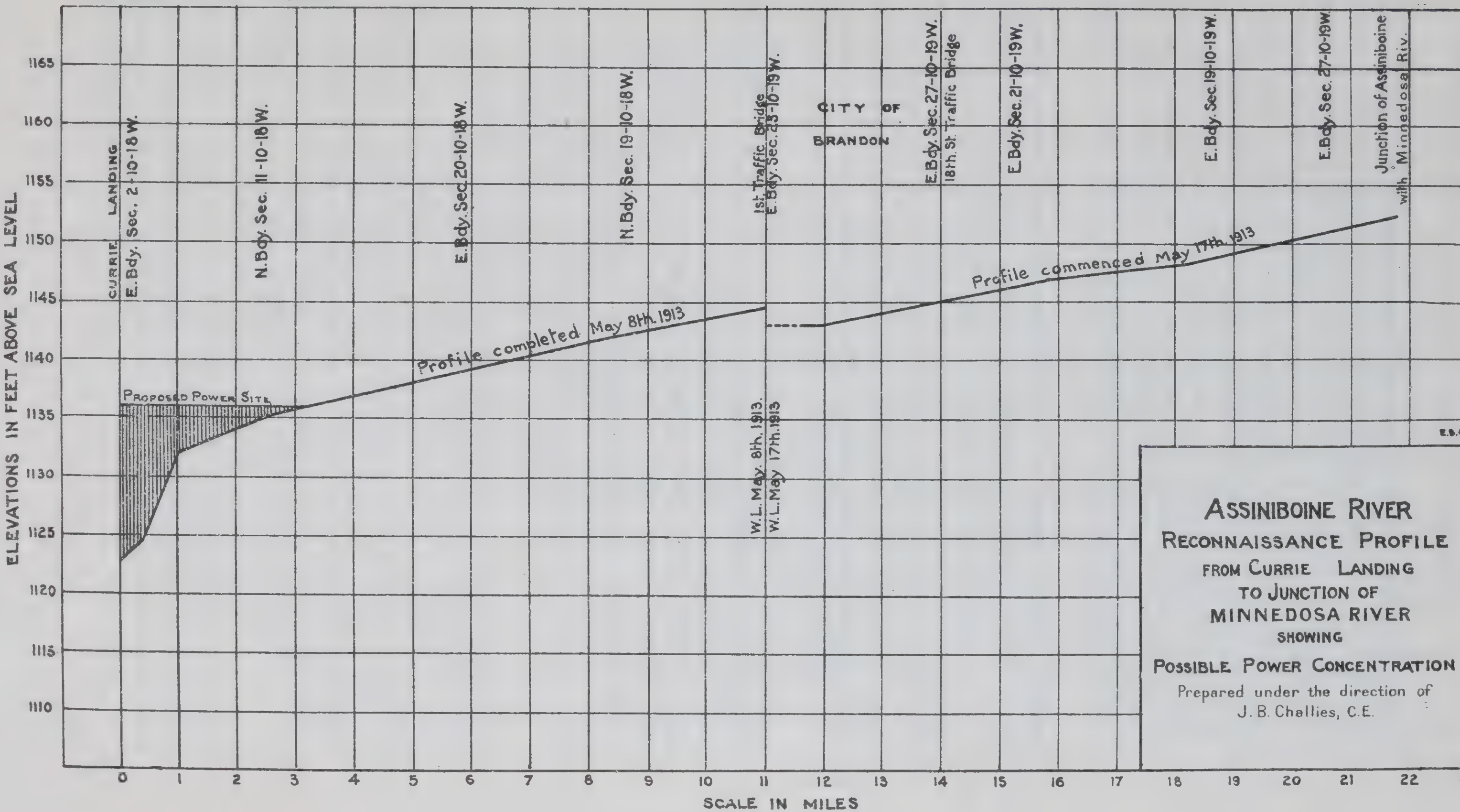
Throughout the basin of the river in Manitoba the land is practically all settled and utilized for agricultural purposes. The little standing timber is chiefly small and of little value except for firewood.



Minnedosa River—Reservoir at Rapid City

Assiniboine River—Old Dam at Millwood

COMMISSION OF CONSERVATION



ASSINIBOINE RIVER

RECONNAISSANCE PROFILE

FROM CURRIE LANDING TO JUNCTION OF MINNEDOSA RIVER

SHOWING

POSSIBLE POWER CONCENTRATION

Prepared under the direction of J. B. Challies, C.E.

The Assiniboine flows through the most thickly settled sections of Manitoba. On its banks are the three largest cities in the province, namely, Winnipeg, Portage la Prairie and Brandon, while its confluence with the Red is directly opposite the city of St. Boniface.

In the lower reaches it can be navigated by boats of small draught, but, on account of its very winding nature and the numerous shoals, it is not used for commercial navigation. At almost any point in its length in Manitoba, it is easily accessible from good roads and prairie trails. It is crossed by numerous lines of railways and is closely paralleled by them for a large percentage of its length within the province.

Precipitation.—From the records of the meteorological stations scattered throughout its basin, the average annual precipitation for its drainage area is found to be approximately seventeen inches.

During the spring freshets, the river is subject to wide variations in flow; during 1913, a range of 12 feet was noted between the extreme high and low water levels. The period of high water, however, does not cover more than three weeks, and the average variation during the remainder of the year is approximately five feet.

No Power Developments on River.

There are no power developments on the river in Manitoba, the development at Millwood having been destroyed in the spring of 1913. A total head of 18 feet was obtained, and the power operated a flour mill. While a large part of the wooden dam still remains in fairly good condition, the foundations of the mill itself were destroyed by the scouring action of the water, and the building, chiefly of timber construction, was carried down the river. A photograph of this site, in its present condition, is shown facing page 42.

Three surveys of possible dam sites for the development of power for Brandon have been made on the river in the vicinity of the city. One of these was made in 1902 by the late Cecil B. Smith for the Western Electric Light and Power Company. The second was made by R. E. Speakman, city engineer of Brandon, for the purpose of investigating a proposition made to the city by the above mentioned power company. During 1913, a reconnaissance, by the Manitoba Hydrometric Survey, was made under the direction of the late G. H. Burnham, at Currie Landing, about 12 miles below Brandon.

The results of these surveys show that, in the vicinity of Currie Landing (see profile facing page 42), a possible head of 18 feet is obtainable. This head would probably be diminished somewhat during high water.

Assuming a minimum mean monthly flow of 45 second-feet, 74 h.p. could be developed at Millwood with 80 per cent efficiency under the 18 feet of head, while for the period of six months, from May to October, with an assumed flow of 118 second-feet, 193 h.p. would be possible. At the Currie Landing site, a minimum mean monthly flow of 60 second-feet may be assumed, which, with an efficiency of 80 per cent under a head of 18 feet, can produce 98 h.p.; for the period of six months, May to October, an assumed flow of 180 second-feet would give 295 h.p. at this site.

DISCHARGE OF ASSINIBOINE RIVER, AT MILLWOOD, MAN.
(Drainage area, 7,590 square miles)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1913				
January			170*	.022
February			160*	.021
March			200*	.026
April			4,794*	.632
May	6,351	3,305	4,520	.596
June	3,235	1,025	1,858	.245
July	4,073	1,210	3,381	.445
August	3,908	1,658	2,534	.334
September	1,609	758	1,104	.145
October	890	535	705	.093
1914				
January	111*	89*	101*	.013
February			96*	.013
March			91*	.012
April	3,800	90*	1,740*	.229
May	4,649	2,352	3,655	.481
June	2,184	544	1,185	.156
July	540	196	362	.048
August	184	103	126	.017
September	136	105	118	.016
October	160	113	144	.019
November	157	80	131	.017
December	117	20	74	.010
Year	4,649	20	660	1.031
1915				
January		51	45*	.006
February			63*	.008
March			65*	.009
April	1,202		590*	.078
May	373	199	247	.032
June	329	163	257	.034
July	625	258	370	.049
August	308	88	149	.020
September	136	98	119	.016
October	163	130	140	.018
November	163		130*	.017
December			75*	.010
Year	1,202	51	188	.025

* Estimated

DISCHARGE OF ASSINIBOINE RIVER, NEAR BRANDON, MAN.
(Drainage area, 34,500 square miles)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1912				
July (4-31)	2,510	1,822	2,057*	.06
August	2,081	1,270	1,711	.05
September	5,069	1,472	3,065	.089
October	5,223	2,410	3,542	.103
November (1-25)	2,365	1,426	1,920*	.056
December			400*	.012
1913				
January			400*	.012
February			400*	.012
March			400*	.012
April			5,664*	.164
May			10,099*	.293
June	5,303	2,178	3,464	.100
July	5.245	2,103	4,043	.117
August	4,548	2,395	3,550	.103
September	2,343	1,140	1,620	.047
October (1-25)	1,121	945	1,029*	.03
1914				
January			200*	.006
March			400*	.012
April			3,000*	.087
May	5,850	4,320	5,350	.155
June	4,200	1,030	2,400	.070
July	1,140	435	774	.022
August	529	203	280	.008
September	242	169	189	.005
October	330	148	235	.007
November			250*	.007
December	215	106	173	.005
1915				
January			65*	.002
February		57	60*	.002
March			90*	.003
April	2,464		900*	.026
May	684	502	580	.017
June	691	357	462	.013
July	876	379	582	.017
August	722	187	358	.010
September	313	171	245	.007
October			180*	.005
November			170*	.005
December			100*	.003

* Estimated

DISCHARGE OF ASSINIBOINE RIVER, AT HEADINGLY, MAN.
(Drainage area, 59,420 square miles)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1913				
January			*500	.008
February			*400	.007
March			*400	.007
April			*5,191	.087
May	14,069	7,030	1,225	.021
June	6,768	2,800	4,541	.075
July	5,355	2,335	3,801	.064
August	5,035	2,619	3,978	.067
September	2,693	1,390	2,021	.034
October	1,390	827	1,182	.020
1914				
January	420	305	354	.006
February	324	212	318	.005
March			*325	.005
April			*3,400	.057
May	6,550	5,550	6,100	.103
June	5,900	1,470	3,300	.056
July	1,730	762	1,240	.021
August	840	440	571	.009
September	495	385	432	.007
October	484	340	409	.007
November			*300	.005
December	275	88	195	.003
Year	6,550	88	1,410	.284
1915				
January	132	114	122	.002
February	163	126	140	.002
March	371	159	210	.004
April	1,685	342	1,070	.018
May	1,380	653	843	.014
June	694	543	632	.011
July	829	543	667	.011
August	900	310	545	.009
September	488	236	382	.006
October	494	365	438	.007
November			*350	.006
December			*160	.003
Year	1,685	114	463	.008

* Estimated.

Souris River

The Souris river rises in the southern portion of Saskatchewan, about 20 miles northwest of Weyburn. The upper course of the river is southeasterly to North Dakota, where it bends to the northeast, following this general course until it joins the Assiniboine river, about 22 miles southeast of Brandon.

Large Drainage Area

The basin of the Souris is probably larger in comparison with its flow than that of any other western river; it includes an area of 22,860 square miles. Its extreme width is 160 miles, and the length, from headwaters to mouth, is 200 miles. The river, following its windings, is nearly 550 miles long and has a width varying from 85 to 170 feet. The upper portion of the basin in Manitoba consists, principally, of a sandy or gravelly sub-stratum, overlain with a light alluvial soil. In this area the valley is shallow, but, near the mouth, the soil becomes heavier and the valley much bolder, with steep banks occasionally rising to a height of 150 to 200 feet. The banks of the stream vary from 20 to 30 feet in height, and consist of sand, gravel and clay. The land above the banks of the valley is, as a rule, bare prairie, with very little timber, all of which is small and in isolated clumps.

The difference between high and low water levels of the river in some districts has been noted as being 20 feet, but this is an extreme condition; the normal variations are about 10 or 12 feet.

In Manitoba the basin is well settled, with several thriving towns along the river, including Wawanesa, Souris, Hartney and Melita.

The river is not navigable except by rowboat or canoe, and travelling would be difficult even in this manner during low water periods. Passing through a well-settled country, with a soil which tends to be rather sandy, the roads are good, and the river is easily accessible therefrom at many points. It is also in close touch with railways throughout its entire length. From the town of Souris, the Estevan branch of the Canadian Pacific railway closely follows the course of the river to within a short distance of the point at which it crosses the international boundary from North Dakota.

Extremely Small Run-off

Precipitation.—The precipitation over the area drained by the Souris is very small, varying from 15 to 18 inches, and the actual run-off for the year ending Oct. 31, 1913, was found to be 1.4 in. per square mile of drainage area.

This extremely small run-off from the large area drained may be attributed to:—(1) Small rainfall and snowfall. (2) The topography of the country. The flat prairie country bordering the river holds the water in the sloughs, where it evaporates rapidly, aided by the winds which have full play across the open stretches. (3) The distribution of the rainfall. It is noted from meteorological reports that the greatest rainfall in this area comes in the growing season of the year when evaporation losses are also greatest.

Between its confluence with the Assiniboine and the point where it first enters Manitoba, it descends 305 feet, or about two feet per mile.

The flow in the river is very irregular and, as it sometimes goes down to nil during summer and winter, no definite estimates for power are given.

A power site, situated about one mile above Souris, Man., has been investigated by the Department of Public Works, Manitoba, in the interest of the town of Souris. A head of approximately 25 feet could be created by a dam constructed just above a rapid which has a fall of one and one-half feet. This site was first investigated in July, 1906, by Mr. K. S. Patrick, who found the flow at that time to be over 4,600 cubic feet per second, giving 1,300 theoretical h.p. with 25-feet head. The same site was afterwards inspected by Mr. A. Livingston in the month of March for winter conditions. The flow was then found to be 100 cubic feet per second, giving 285 minimum theoretical h.p., with the 25-feet head. Mr. Livingston further states that from 600 to 800 h.p. would be available for eight months in the year. Subsequent stream-flow observations show that the available power would be much less than Mr. Patrick's estimate. A stream gauging station was established at Wawanesa, in October, 1912, by the Manitoba Hydrometric Survey. The following is a summary of the records obtained:

DISCHARGE OF SOURIS RIVER, NEAR WAWANESA, MAN.

(Drainage area, 22,500 square miles)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1912				
October (7-31)	88	79	80*	.003
November (1-15)	92		54*	.002
December			20*	.001
1913				
January			10*	.0004
February			5*	.0002
March			10*	.0004
April (15-30)	1,425		966	.043
May	1,445	264	917	.041
June	237	73	133	.006
July	78	46	59	.0026
August	70	45	54	.0024
September	62	50	55	.0024
October	60	39	50	.0022
1914				
January			5*	.0002
February		0*	0*	
April	1,090		500	.022
May	1,000	348	683	.030
June	334	162	239	.011
July	204	123	163	.007
August	130	75	98	.004
September	81	33	55	.002
October	47	16	28	.001
November	50		20*	.0009
December			5*	.0002

DISCHARGE OF SOURIS RIVER, NEAR WAWANESA, MAN.—*Continued*

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1915				
January			*0	
February			*0	
March			*2	.000
April			*95	.004
May	86	45	67	.003
June	116	11	50	.002
July	62	11	40	.002
August	22	0	4	.000
September	96	0	30	.001
October	57	11	34	.002
November			*8	.000
December			*2	.000

* Estimated

A stream gauging station was established near Estevan, Sask., by the Irrigation branch of the Department of the Interior in 1911. The following is a summary of discharges:

DISCHARGE OF SOURIS RIVER, NEAR ESTEVAN, SASK.
(Drainage area, 4,550 square miles)

Month	Discharge, in second-feet			
	Maximum	Minimum	Mean	Per square mile
1911				
June (23-30)	16.5	7.7	12.2	.003
July	22.7	.60	4.39	0.001
August	4.1	.50	1.49	0.003
September	4.7	.42	1.91	0.0004
October	73.0	.50	33.8	0.007
November (1-15)	34.0	9.6	19.1	0.004
1912				
June (25-30)	22	18.8	20.2	0.004
July	15	9.5	13.2	0.003
August	8.8	3.6	5.15	0.001
September	4.0	2.3	3.02	.0006
October	10.1	2.6	6.67	0.0010
November	6.5	2.8	4.41	0.001
December	3.3	1.4	2.26	0.0005
1913				
January	2.20	0.00	0.287	0.0001
February	9.80	0.00	2.420	.0005
March	319.00	9.80	44.000	.0100
April	1,705.00	30.00	409.700	.0900
May	33.00	11.70	17.300	.0040
June	31.00	3.50	12.400	.0030
July	39.00	8.10	21.400	.0050
August	8.60	2.30	4.230	.0010
September	1.75	0.00	0.659	.0001
October	3.30	0.00	1.050	.0002
November	2.50	2.00	2.230	.0005
December	2.50	0.33	0.961	0.0002

DISCHARGE OF SOURIS RIVER, NEAR ESTEVAN, SASK.—*Continued*

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1914				
January	0.43	0.07	0.30	0.00007
February	0.57	0.34	0.50	.00011
March	200.00	0.49	86.00	.019
April	500.00	77.00	229.00	.05
May	132.00	36.00	65.00	.014
June	613.00	28.00	155.00	.034
July	34.00	3.60	14.40	.0032
August	5.20	0.80	2.20	.0005
September	1.50	0.46	0.83	.00018
October	2.00	0.59	1.35	.0003
November	1.20	0.53	0.76	.00017
December	1.10	0.90	1.00	0.00022
1915				
January	1.11	.96	1.01	.000222
February	5.90	.81	1.85	.000407
March	3.80	.81	1.86	.000410
April	3.80	2.10	3.00	.000660
May	3.00	1.24	1.96	.000430
June	2.40	.47	.99	.000218
July	8.90	.47	1.20	.000264
August	.60	.01	.28	.000061
September	.05	.01	.04	.000009
October	.06	.01	.05	.000011
November	1.05	.04	.43	.000094
December	.76	.60	.72	.000158

Discharge observations on this river, covering a longer period, are available for a station established by the U. S. Geological Survey at Minot, N. Dak. The following is a summary of same:

MONTHLY DISCHARGE OF SOURIS RIVER, AT MINOT, N. DAK.
(Drainage area, 8,400 square miles)

Month	Discharge, in second-feet			
	Maximum	Minimum	Mean	Per square mile
1904				
Spring flood (estimated)	12,000			
July	427	152	258	.031
August	152	108	114	.014
September	108	68	81.7	.0097
October	87	68	71.8	.0085
November (1-25)	87	50	64.3	.0077
1905				
March (5-31)	108	78	97.6	.012
April	78	33	61.2	.0073
May	130	33	64.1	.0076
June	119	68	98.6	.012
July	108	59	81.3	.0097
August	108	33	68.4	.0081
September	87	10	30.3	.0036
October	20	10	15.5	.0018
November (1-28)	33	20	24.6	.0029

DISCHARGE OF SOURIS RIVER AT MINOT, N. DAK.—*Continued*

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1906				
April	1,320	240	454	.054
May	218	108	159	.019
June	499	286	401	.048
July	286	130	214	.025
August	130	31	61.9	.0074
September	31	18	26.2	.0031
October	18	8	16.1	.0019
November (1-18)	18	18	18.0	.0021
1907				
April	621	35	183	0.022
May	2,190	707	1,500	.179
June	2,100	268	820	.098
July	885	243	470	.056
August	219	52	104	.012
September	52	20	36.2	.0043
October			20	.0024
November			16	.0019
December			11	.0013
1908				
January			8	.00095
February			6	.00071
March			20	.0024
April	644	174	311	.037
May	163	109	136	.016
June	407	152	239	.028
July	174	99	125	.015
August	120	80	94.1	.011
September	89	28	63.0	.0075
October	35	15	23.1	.0028
November	35		30	.0036
December			15	.0018
Year	644		89.2	.011
1909				
March (21-30)	546	243	411	0.049
April	1,080	436	727	.087
May	422	231	289	.034
June	546	174	322	.038
July	163	29	82.1	.0098
August	70	11	37.7	.0045
September	52	.5	15.5	.0018
October	.57	.5	.509	.000061
November	.57	.5	.507*a*	.000060
1910				
January			0.5*b*	0.000060
February			.5*b*	.000060
March	196		127	.015
April	207	141	171	.020
May	141	79	110	.013
June	70	28	46.6	.0055
July	38	10	21.9	.0026
August	7	.3	2.13	.00025
September	.6	.2	.40	.000048

a Partly estimated.

b Estimated.

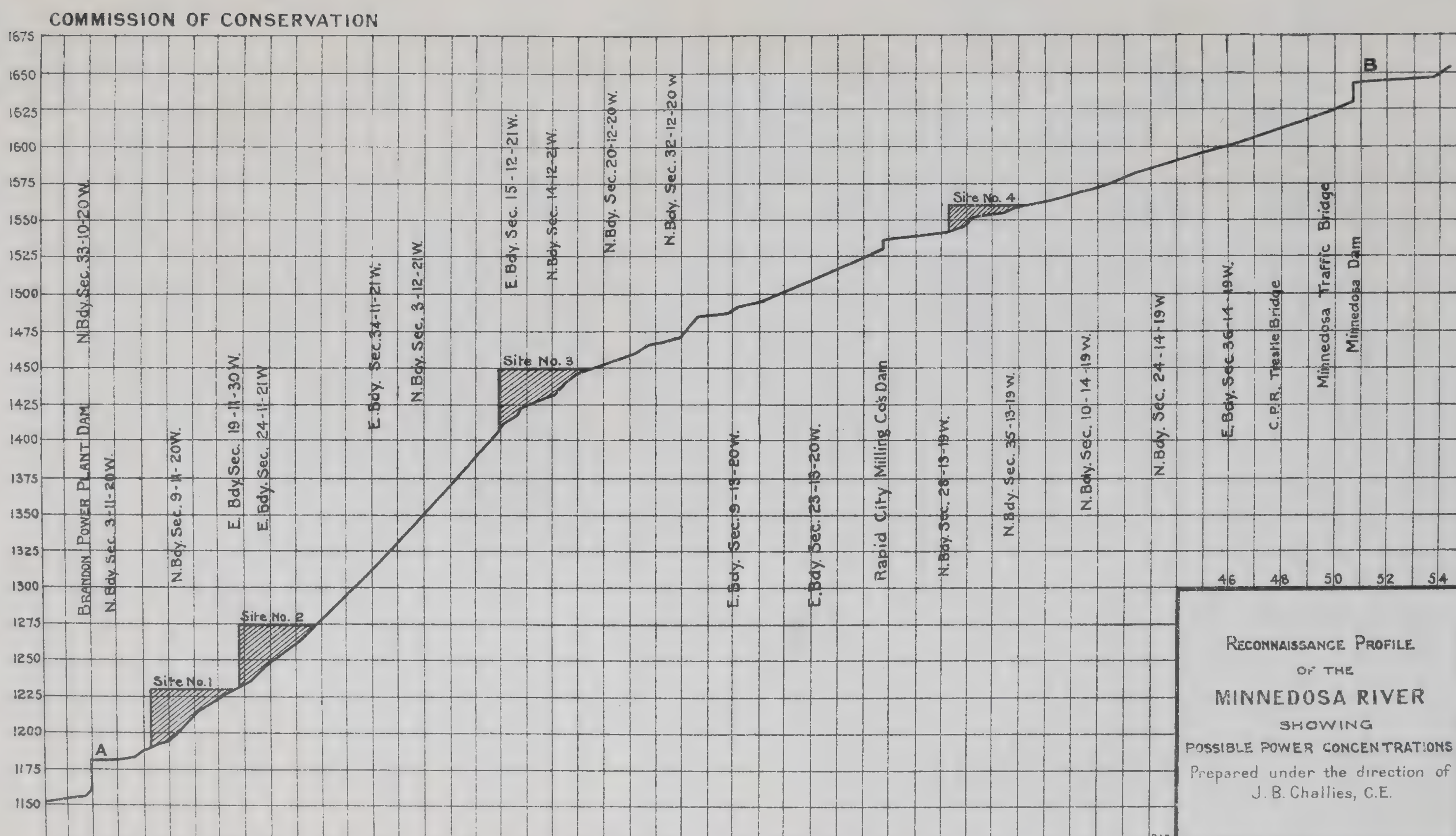
DISCHARGE OF SOURIS RIVER AT MINOT, N. DAK.—*Continued*

Month	Discharge, in second-feet			
	Maximum	Minimum	Mean	Per square mile
1910—*Con.*				
October	.6	.5	.52	.000061
November	.7	.5	.57	.000068
December			.5*b*	.000060
1911				
March (19-31)	14	2.6	6.80	0.00081
April	744	14	339	.040
May	722	146	449	.053
June	214	55	138	.016
July	64	14	34.1	.0041
August	24	3.6	15.6	.0019
September	4.4	.7	2.27	.00027
October	7.6	.7	2.55	.00030
November	18		10.1	.0012
December			2	.00024
1912				
March (24-31)	450	13	173	.021
April	1,200	306	695	.083
May	983	235	511	.061
June	498	69	239	.028
July	69	60	66.7	.008
August	60	30	42.7	.005
September	52	24	33.5	.004
October	69	24	48.0	.006
November	69	30	42.3	.005
1913				
March			59	.007
April	1,080	266	795	.095
May	266	90	144	.017
June	90	23	30.4	.004
July	174	17	74.9	.009
August	125	68	87.3	.010
September	79	5.6	20.6	.002
October	5.6	2.5	3.17	.0004
November	47	3	24.5	.003
1914				
March	665		186	.022
April	1,080	266	646	.077
May	293	150	227	.027
June	482	137	265	.032
July	200	9	47.8	.006
August	9	2	5.10	.0006
September	6.5	1.8	4.07	.0005

NOTE.—Discharge has been estimated for period October 1, 1907, to March 31, 1908, and is very approximate, there being only one measurement during the period. Discharge for November 29 to December 31, 1908, has been estimated and is only approximate.

Minnedosa River

The Minnedosa (Little Saskatchewan) river rises in the southerly portion of Riding Mountain forest reserve, and flows in a southeasterly direction until it reaches Minnedosa. At this town the river turns



Reconnaissance Profile
of the
MINNEDOSA RIVER
showing
POSSIBLE POWER CONCENTRATIONS
Prepared under the direction of
J. B. Challies, C.E.

Douglas L. McLean Chief Engineer
Stuart S. Scovil Asst. Chief Engineer

almost at right angles, and flows southwesterly, until within about 15 miles of its mouth, where it resumes its original course to the southeast and joins the Assiniboine river. The confluence with the latter occurs eight miles west of Brandon, almostly direct south of the headwaters.

River Basin and Banks

The watershed of the river includes an area of 1,640 square miles, the greater portion of which is hilly and undulating. The width of the basin in the upper reaches approximates 45 miles, and its length, from mouth to headwaters, 60 miles. In its upper basin there are numerous small lakes, draining into the upper tributaries; from this section most of the drainage is derived. In the lower reaches of the river very few tributaries are met with. The largest single drainage entering it, Rolling river, is encountered about 13 miles north of Minnedosa.

Its course throughout is very tortuous, and though, as above noted, the length of the basin from headwaters to mouth is 60 miles, the actual length of the river is 125 miles.

The valley of the river is well defined. The banks vary in height from 100 to 300 feet, while the distance between them varies from 1,000 feet to a mile and a quarter.

The soil is principally sandy clay, which, in some parts, particularly on the lower levels, is thickly strewn with boulders. This soil generally overlies a stratum of gravel, and, at a depth of about five feet, blue clay is encountered in most sections. Pockets of quicksand also occur but are not common.

The river, almost throughout its entire length, flows over a bed composed of fine gravel and sand, which, in some localities, is thickly covered with large boulders. In width, the bed varies from 50 to 90 feet. No rock outcrops have been noted, and it is not likely that they occur in any portion of the river.

Timber and Vegetation

In the upper reaches, much valuable timber has been observed, but, elsewhere, very little marketable timber is to be had; the country is well settled and the land largely under cultivation throughout the basin. The unbroken land is generally covered with small poplar and scrub.

This basin is one of the oldest settled in the province. The soil is rich, and the section north of Minnedosa is noted for its oat crops, while, in the southern portion, wheat forms the chief product. It contains the settlements of Rivers, Gauthier, Rapid City, Riverdale, Minnedosa, Rolling River and Elphinstone.

The river is navigable only by rowboat or canoe. Throughout its course, with the possible exception of the extreme upper portion of its basin, the roads are in very good condition, and the river easily accessible. It is also in close touch with the different railways along

the lower 100 miles of its course. At no place in this distance is the river farther than six miles from a railway.

Precipitation.—Records for Minnedosa, covering a period of 32 years, give the mean annual precipitation as 18 inches.

In 1913, there was an extreme variation between flood and low water of slightly over five feet. The flood conditions lasted for a period of three weeks, but, with this exception, the maximum variation in the stage of the river has been 2·7 feet.

Power Surveys and Storage

A reconnaissance survey of available water-power sites was made during the summer of 1913 by the Manitoba Hydrometric Survey. The river was examined from the Assiniboine to a point about four miles above Minnedosa, and investigations respecting possible storage were made up to the headwaters above Elphinstone. The profile of the Minnedosa river facing this page gives the location of four possible sites for dams and also the two existing developments, as investigated by this survey.

The lake and stream areas, with the adjacent low land and marshes in the upper basin, which might be utilized for storage purposes, are as follows:—

Andy lake, including Big Jackfish creek ..	1,000	acres
Jackfish lake	1,280	"
Bottle and Spruce lakes	1,100	"
Squaw creek	2,500	"
Clear lake	8,960	"
Proutt lake	350	"
Stuart lake	650	"
Oak lake	1,300	"
Thomas lake	2,000	"
Beauford lake	600	"
Long lake	1,800	"
Sandy lake	2,500	"

Further investigations of the storage possibilities on the above lakes, however, render it extremely doubtful if any feasible storage can be secured in this watershed.

The data at hand show quite a variation in the flow of the river from year to year, but is not sufficient to allow of definite estimates for power. Should a regulated flow of 200 second-feet be feasible, which seems possible during certain years and portions of others, the following power would be available at the different sites with an assumed efficiency of 80 per cent:

Brandon Electric Light.	30	feet of	head	545	horse-power
Minnedosa Power Co. ..	25	"	"	455	"
Dam Site No. 1	40	"	"	730	"
Dam Site No. 2	45	"	"	820	"
Dam Site No. 3	47	"	"	860	"
Dam Site No. 4	20	"	"	365	"

Power Developments

Brandon Electric Light Company

The hydro-electric plant of this company is situated on the Minnedosa river, one mile above its junction with the Assiniboine and nine miles west of the city of Brandon. A timber dam, 260 feet long, gives a head of 30 feet. The power-house contains two units, each of which consists of a 54-inch wheel geared to a 300-k.w. generator. The electrical energy is generated at 60 cycles, three phase, 1,100 volts, and stepped up to 11,800 volts by six 100-k.w. transformers. A nine-mile transmission line of No. 6 hard-drawn copper wire carries the energy to Brandon, where it is received at the company's steam station and stepped down to 2,300 volts by a set of transformers similar to that at the power-house.

With regard to the fluctuation in the flow of the river at this point, the operating company states there is a sufficient supply of water during eight months of the year, commencing about the middle of April, but that there is very little water between January and April. Partly as a result of these conditions, and partly on account of having to supply an important central steam-heating system operated by the company, the water-power plant is practically inoperative during the winter months when the energy is derived from steam power.

Auxiliary Steam Plant

The company's steam plant, located in the centre of the city, in addition to the steam-generating equipment, includes the water-power plant sub-station, distributing system, central steam-heating system, and two 300-k.w. rotary converters for the street railway. The maximum demand, not including the street railway load, is 600 k.w. in summer and 1,100 k.w. in winter. Before the street railway commenced operations, the hydro-electric plant carried all the load from April 1st to September 1st, and part of it from then to December, closing down in winter. The requirements of the street railway have added 300 k.w. to the foregoing figures.

Minnedosa Power Company

This company has built a dam across the Minnedosa river, creating a head of about 25 feet, immediately above the town of Minnedosa. The dam is approximately 1,800 feet long, 125 feet wide at the base, and is constructed of earth and heavy clay with concrete core. The power-house is situated several hundred feet below the dam. At present it contains one unit but provision is made for the installation of a second. The unit comprises a 31-inch horizontal wheel, direct connected to a 250-k.w., 3-phase generator. The electrical energy is generated and distributed at 2,200 volts. The maximum load carried is 150 h.p., but it is expected that, with the help of the local storage created by

the dam, combined with the storage available in Clear lake, this may be materially increased. The local storage is one-quarter of a mile wide and three and one-half miles long. A storage dam has been erected on the outlet of Clear lake which is 35 miles distant in a straight line, but about 200 miles following the river.

A steam plant of 125 h.p. capacity served the town before the installation of the hydro-electric plant.

A gauging station was established in January, 1913, by the Manitoba Hydrometric Survey. The following is a summary of the results obtained:

DISCHARGE OF MINNEDOSA RIVER, NEAR RIVERDALE, MAN.
(Drainage area, 1,250 square miles)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1913				
January			50*	.04
February			60*	.05
March			60*	.05
April	1,942	507	927*	.74
May	901	180	520	.42
June	487	154	330	.26
July	507	211	372	.30
August	475	99	235	.19
September	126	12	61	.05
October	271	13	72	.06
1914				
January			20*	.016
February			20*	.016
March			20*	.016
April	1,336	510	937*	.750
May	808	317	590*	.472

* Estimated.

NOTE.—Records for the winter of 1914-15 show that at times the flow of Minnedosa river becomes negligible.

DISCHARGE OF MINNEDOSA RIVER AT BEILBY'S BRIDGE
(Drainage area, 1,120 square miles)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1915				
March			*2	.002
April	250		*95	.085
May	75	37	56	.050
June	107	36	78	.070
July	121	53	80	.071
August	64	40	48	.043
September	77	36	54	.048
October	135	69	88	.079
November	85		*40	.036
December			*8	.007

* Estimated.

Birdtail Creek

This creek, which rises in the western part of the southern slope of Riding mountain, flows mainly in a southerly direction, turning eastward a few miles above Birtle. Below Birtle it resumes its southerly course and flows into the Assiniboine in township 15, range XXVII, west of first meridian.

At two or three power sites near Birtle low heads could be created by dams. One of these has been investigated by the Manitoba Public Work Department, on behalf of the town of Birtle. The report states that the site is situated one mile east of the town, where the river takes a wide sweep at the foot of a steep hill and, falling through a small rapid, divides into two streams, which re-unite a short distance downstream. The north bank of the river is low for a distance of about 400 feet, beyond which it rises abruptly to a height ot nearly 20 feet. The banks are of a sandy loam containing numerous field stones. The dam can be constructed to give an effective head of 18 feet, which could be increased to 24 feet if required. The power is estimated at 250 h.p., available for nine months of the year.

One of the other possible sites is situated one-half mile below the town, and a third 15 miles northeast of the town. Both of these are at abandoned grist and saw mills. Each of them had between eight and ten feet head but auxiliary steam plants were used.

With regard to storage on this river, it is reported that there are two lakes in the Riding Mountain forest reserve, each of about one square mile in area. These could be raised five or six feet, but unfortunately they are rather far distant, being, approximately, 40 miles in a straight line, or 150 miles following the river, from Birtle.

Qu'Appelle River

The Qu'Appelle river, one of the largest tributaries of the Assiniboine, has an interesting glacial history. Its valley is quite uniformly about one mile wide and is from 110 to 350 feet below the general level of the surrounding region; the river flows in a winding course, here and there traversing long lakes. Last Mountain lake, one of its tributaries, is about fifty miles long and from one to two miles wide; the descent from here to the mouth of the Qu'Appelle is 335 feet.

There are several irrigation and many industrial water-rights in the basin of the Qu'Appelle.

A gauging station was established at Lumsden, Sask., by the Irrigation branch of the Interior Department in 1911. The following is a summary of the observations taken at this station since that year:

MONTHLY DISCHARGE OF QU'APPELLE RIVER, AT LUMSDEN
(Drainage area, 6,160 square miles)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1911				
May (12-31)	172.0	31.0	83.9	0.013
June	319.0	19.0	133.0	0.022
July	255.0	13.0	42.6	0.007
August	16.0	11.0	12.9	0.002
September	144.0	11.0	32.4	0.005
October (1-28)	30.0	12.0	15.4	0.002
November (12-30)	3.86	3.20	3.72	0.001
December	3.10	2.14	2.77	
1912				
January	1.97	0.33	0.727	0.0001
February	40.4	0.33	0.355	0.0001
March	166.0	0.26	15.8	0.002
April	867.0	94.0	395.0	0.064
May	884.0	81.0	523.0	0.084
June	308.0	68.0	158.0	0.002
July	128.0	55.0	86.4	0.014
August	48.0	27.0	34.1	0.006
September	37.0	21.0	29.0	0.005
October	30.0	19.0	23.6	0.004
November	24.0	2.98	16.6	0.003
December	3.24	2.36	2.71	0.0004
1913				
January	3.4	0.0	10.90	0.0020
February	3.7	0.6	2.49	0.0004
March	163.0	0.0	60.90	.0090
April	807.0	101.0	428.00	0.0700
May	107.0	62.0	82.00	0.0130
June	79.0	25.0	46.40	0.0070
July	83.0	30.0	46.80	0.0070
August	46.0	21.0	31.20	0.0050
September	25.0	8.0	15.40	0.0020
October	13.1	5.0	9.16	0.0010
November	9.0	6.1	7.47	0.0010
December	6.9	2.2	3.80	0.0006
1914				
January	2.70	0.15	1.14	0.0002
February	0.06	0.02	.007	.000001
March	4.30	0.09	1.85	.0003
April	187	7.5	86	.014
May	65	15.9	33	.0054
June	38	15.6	24	.0039
July	35	12.5	19.8	.0032
August	12.5	2.6	7.5	.0012
September	19.6	2.8	5.4	.0009
October	11.5	4.5	6	.001
November	5.4	2.9	4.4	.0007
December	4.4	0.77	2.4	0.0004

MONTHLY DISCHARGE OF QU'APPELLE RIVER, AT LUMSDEN.—*Continued*

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1915				
January	1.05	.20	.77	.00012
February	.20		.06	.00001
March	.48		.08	.00001
April	18.70	.66	9.00	.00146
May	17.00	6.90	11.20	.00182
June	9.10	6.30	7.60	.00123
July	8.70	3.40	5.90	.00096
August	4.30	1.80	2.60	.00042
September	5.80	2.00	3.70	.00060
October	12.50	5.00	9.30	.00150
November	9.30	2.09	3.80	.00062
December	2.28	1.37	2.10	.00034

Moose Jaw Creek

Moose Jaw creek rises in the north-western slope of the Missouri Coteau. Its extreme headwaters are near Moreland, Sask., in township 9, range XX, west of second meridian. It flows north-westerly until it reaches the city of Moose Jaw, and thence in a north-easterly direction, finally emptying into the Qu'Appelle river near Buffalo-pound lake. From the headwaters to the city of Moose Jaw the drainage area is estimated to be about 1,830 square miles. This area is almost entirely devoid of tree growth, except that the valley is lined with brush in the vicinity of Moose Jaw.

General Description of Stream

Throughout its length the creek flows in a very tortuous but well-defined channel. The upper portion of the valley is merely a shallow depression, but gradually increases in depth, until at Drinkwater it is about 30 feet deep and at Moose Jaw about 80 feet deep. The fall in the creek is very slight, particularly between Drinkwater and Moose Jaw, where the total descent is only 67.5 feet, or an average of 2.3 feet per mile of valley.

The Canadian Pacific railway has dams at Milestone, Rouleau, Drinkwater and Pasqua and two at Moose Jaw. There is also a municipal dam in section 19, township 15, range XXIV, west of second meridian, which supplies water to the neighbourhood during periods when there is no flow in the creek. The volume of water diverted in each case is small, as the Canadian Pacific only uses it for its engines.

A gauging station was established at McCarthy's ranch, section 16, township 16, range XXVI, west of second meridian, by the Irrigation branch of the Interior Department in 1910. The following is a summary of observations since that year:

DISCHARGE OF MOOSE JAW CREEK, AT McCARTHY'S RANCH

(Drainage area, 1,719 square miles)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1910				
April (7-30)	27.45	1.10	6.80	0.0039
May	112.80	0.51	29.21	0.0170
June	43.60	5.35	22.77	0.0132
July	4.35	0.00	1.18	0.0007
1911				
March (19-31)	72.0	0.70	31.90	0.018
April	365.0	29.00	188.00	0.109
May	123.0	2.00	37.80	0.022
June	285.0	4.80	71.00	0.041
July	21.0	0.50	2.80	0.0016
August	0.8	0.00	0.21	0.0001
September	0.4	0.00	0.08	0.0000
October	39.0	0.00	11.50	0.0067
November (28 days)	8.5	1.60	4.15	0.0024
December	1.5	0.08	0.55	0.0003
1912				
January	0.14	0.01	0.095	0.0000
April (5-30)	634.0	52.0	257.2	0.149
May	1,329.0	39.0	521.2	0.306
June	111.0	14.0	48.5	0.028
July	54.0	1.6	23.8	0.014
August	6.2	0.95	2.87	0.0017
September	1.55	0.40	0.94	0.0005
October	2.6	1.40	1.93	0.0011
November	2.0	0.05	1.32	0.0008
December	0.14	0.02	0.049	0.0000
1913				
April	313.00	15.10	87.10	0.051
May	13.70	0.93	6.37	.004
June	2.85	.28	0.98	.0005
July	32.00	.33	12.09	.007
August	3.90	.09	0.64	.000
September	0.60	.00	.12	.000
October	.38	.00	.20	.000
November	.60	.33	.38	.000
December	0.33	0.00	0.10	0.000
1914				
March	15.00	8.00	1.10	0.0005
April	198.00	10.40	66.00	0.038
May	13.60	1.52	5.60	0.003
June	9.30	1.30	3.40	0.002
July	1.39	0.04	0.43	0.000
August	0.04	0.00	0.01	0.000
November	19.00	0.00	2.40	0.001
December	1.00	0.00	0.34	0.000
1915				
April	3.74	.28	1.47	.00086
May	1.12	.27	.41	.00024
June	.33	.24	.28	.00016
July	.24	.01	.13	.00008

Shell River

Shell river, one of the largest tributaries of the Assiniboine, rises in the northerly portion of Duck mountain, and empties into the Assiniboine about three miles above the village of Shellmouth.

The general direction of the river is almost due south from its source to a point within five miles of its mouth, where it bends sharply to the west and joins the Assiniboine.

Nature of River Basin and Banks

The drainage basin, near the mouth of the river, is narrow, being confined between the watersheds of the Valley and Assiniboine rivers; but, in the upper reaches, it broadens out to approximately 35 miles in width, where it adjoins the watershed of Swan river. It is in this upper section that most of its drainage is obtained, though throughout its course it is fed by springs and short streams. The largest tributary enters the river about 70 miles from the mouth, and is known as the East branch.

The length of the basin from north to south is approximately 60 miles, while the river itself, following its windings, has a length of 90 miles.

Of the smaller rivers of the province, the Shell has one of the most beautiful valleys. It varies in depth from 100 feet, near the headwaters, to 350 feet, about four miles from its mouth, and has an average width of three-quarters of a mile.

The banks are mostly of a gravelly nature, strewn with boulders and overgrown with scrub and small poplar, while the agricultural land on the plateaus on either side will compare very favourably with the best in the province. The bed of the river, which varies between 50 and 90 feet in width, is of a gravelly nature throughout and strewn with large boulders.

Throughout its length there are no distinct falls, but numerous rapids occur where the valley narrows and the bed is contracted.

Valuable Timber District

Valuable timber is found in the Duck Mountain forest reserve on the upper waters. Southward, the timber has been burnt over, and scrub and light poplar cover the unbroken land, while, in the bottom of the valley, there are considerable quantities of spruce and tamarack. Some splendid groves of large elms are found on the flats of the junction of the Shell and Assiniboine.

There is a variation of about four feet between high water, which usually occurs during the months of May and June, and the low water in September. The river is not subject to sudden changes nor to excessive floods, its rise and fall being normally steady and gradual.

On account of the shallowness and the numerous rapids encountered, the stream could only be navigated by canoe. It is crossed by trails at various points, and, for a considerable distance in its middle length, trails follow its course closely. The Canadian Northern railway crosses it at Shevlin.

Although the southerly portion of the basin is well settled, there are only two small villages on the river itself, one at Asessippi, about four miles from the mouth, and the other at Shevlin, 25 miles upstream.

Asessippi possesses an old flour and grist mill which has been operated by water power since 1884. Russell is situated 14 miles due south of Asessippi, and a splendid, well settled, farming country lies between the two towns.

The precipitation records taken at Russell, ten miles south of the drainage area, cover a period of nine years and give a mean yearly rainfall of 16.4 inches. Records taken at Swan River, north of the drainage area, and covering a period of four years, show a precipitation of 20·8 inches, giving a mean yearly precipitation of approximately 18 inches for the basin. Assuming 25 per cent of this as actual run-off, the mean yearly discharge would be 288 second-feet, or 0·33 second-feet per square mile of drainage area.

Discharge Measurements.—In November, 1913, the Manitoba Hydrographic Survey established a gauging station on the river, but, as yet, sufficient data have not been collected upon which to base a definite low-water flow. A discharge measurement made by this survey, September 15, 1913, at Asessippi gave 213·5 second-feet. When this measurement was made, the flow, according to local authority, approached very nearly the ordinary low-water level for the year.

Excellent Water-Power Possibilities

Respecting the power development possibilities, no survey work has been done on the river, but casual observations and available information indicate that, for power purposes, this stream is one of the best of the smaller rivers of the province.

From the mouth of the river to the confluence of the East branch, approximately 75 miles, there is a difference in elevation of 600 feet, or 8 feet per mile. This fall is quite evenly distributed in the upper reaches, but is more marked in the lower portion of the river. This natural descent, combined with the high banks, indicates easy development at different points.

The one development on the river at Asessippi has a head of 10 feet and, though using only a small portion of the flow, developed

50 horse-power; at no period of the year was trouble experienced from lack of flow.

As no survey has been made to ascertain possible dam sites, the information as to actual head at any such site is not available, but the following table gives the possible horse-power per foot of head, with an assumed minimum monthly flow. This assumed flow is taken as extending over a period of six months, from May to October, and is subject to revision.

Head in feet	Assumed minimum flow in second-feet during the six open months	Available horse-power at 80 per cent efficiency
1	200	18.2
10	200	182.0
20	200	364.0

Respecting winter flow on the river, a measurement taken on Jan. 20, 1914, recorded only 12 second-feet.

CHAPTER III

Western Tributaries of Lake Winnipeg*

METERING STATIONS ESTABLISHED BY THE MANITOBA HYDROMETRIC SURVEY

Name of river	Situation	When established
Fairford	Fairford	October, 1913
Mossy	Half mile below Fishing river	July, 1913
Valley	Valley River	November, 1912
Swan	Swan River	October, 1912
Red Deer	Hudson Bay junction	July, 1913

Fairford and Dauphin Rivers

The Fairford and Dauphin rivers form the connection between lake Manitoba and lake Winnipeg. Debouching near the extreme north-easterly portion of lake Manitoba, the Fairford river flows north-easterly to lake St. Martin. From the latter lake, the Dauphin river flows due north for a distance of 14 miles; then turning sharply to the east, it continues on this course to Sturgeon bay, on the west shore of lake Winnipeg.

Nature of Watershed

Lake Manitoba, with an area of 1,711 square miles, acts as a collecting basin for practically all the drainage discharged by these rivers. In general terms, this drainage includes the area to the east of the Manitoba escarpment and the watersheds of the Swan and Red Deer rivers. While the upper reaches of the watershed extend into the Riding, Duck and Porcupine mountains, where the country is hilly, and, to a great extent, covered by a forest growth, the greater portion of the area is a slightly undulating prairie. The soil, generally, is clay, overlying beds of gravel, with occasional rock outcrops. Considerable adjacent territory drains into lake Manitoba but the only tributary of any size, other than those already enumerated, is the Whitemud river. Between lakes Manitoba and Winnipeg, the Fairford and Dauphin do not receive any tributaries of importance.

Generally Low Banks

For the first three miles, the banks of Fairford river are well defined, varying from three to ten feet in height and reaching a maximum in the immediate vicinity of the Canadian Northern Railway bridge. Below this

*The data for this chapter were contributed by the Water Power branch of the Department of the Interior.

RED DEER RIVER (MAN.)—AT JUNCTION WITH ETOMAMI RIVER

FAIRFORD RIVER—ABOVE FAIRFORD

point the banks become gradually lower, opening out into a wide expanse of low, marshy land which merges into lake Pineimuta. Below this lake, they range from two to three feet in height, but again merge into swampy shores near lake St. Martin. The banks are composed of light grey clay, in which a few boulders are imbedded.

Where the Dauphin river leaves lake St. Martin, the banks are poorly defined; low lying meadows, subject to overflow in periods of high water, merge into the timber line about one-half mile from either side of the channel. Banks composed of sandy clay, and varying in height from one-half foot to two feet, extend for the first 11 miles, beyond which the river cuts through a sandy ridge, running in an east-and-west direction and having a maximum height of about eight feet. Thence, to the rapids, 12 miles distant, the banks range from one to six feet in height, though, in many places, there are swampy indentations. From the rapids to Sturgeon bay, the height varies from 5 to 32 feet. In this lower reach, numerous limestone ridges cross the river, and rock outcrops are visible in the banks.

The Fairford river varies in width from 500 to 900 feet. It is stated that it is shallow in the vicinity of lake Manitoba, where it flows over a bed of limestone. About one-half mile below this, a small rapid is caused by a bed of limestone and gneiss boulders; there is another rapid in the lower portion of the river.

The Dauphin river, which has an average width of 450 feet, is in places slightly narrower than the Fairford. For the first 11 miles, the bed is sandy and apparently free from large boulders, but, farther downstream, numerous rapids are caused by gravel bars and boulders. Outcrops of limestone are also found in this lower reach of the river.

Dense Forest Growth

While the greater portion of the land along the Dauphin river is covered with a dense growth of poplar, spruce, maple, oak and birch, large areas of swamp land and hay meadows also occur. With the exception of several fields devoted to root crops along the Fairford river, farming is not carried on to any extent in this district.

High water usually comes in the latter part of April and early part of May, while February is the month of low water. The range is ordinarily about four feet, but, in 1902, an extreme range of eight feet was noted.

It is stated that, for the first three miles, the Fairford river does not freeze over, but, below this stretch, an ice cover forms. It is reported that, during the spring break-up on the Fairford, the ice passes away freely, without jams or destruction of the banks, while severe jams do occur on the Dauphin river at the rapids. Evidence that jams at this point have caused a rise of from 15 to 20 feet above

ordinary summer stages, was noted by a field party of the Manitoba Power Survey; boulders, logs and driftwood were found fully 20 feet above the water level of September, 1913.

Transportation Possibilities

The Fairford is navigable by small steamers, though it is claimed that difficulty occurs near lake Manitoba, due to bars.

Navigation for small steamers is possible also on the Dauphin in early summer, but the river is treacherous, due to continual changes of channel. The only point at which the river system is accessible by railway is at Fairford, where the Canadian Northern railway crosses the river. Steamers plying on lake Winnipeg navigate to the mouth of the Dauphin in Sturgeon bay.

In addition to the Indian reserve, there are only two settlements in the district; one is at Fairford, one-half mile from the Canadian Northern Railway crossing of the Fairford river, and the other at Sturgeon bay.

To secure data respecting the improvement of navigation on the Fairford river, surveys extending over the years 1898, 1908, 1910 and 1913 have been made by the Dominion Department of Public Works. In September and October, 1913, a reconnaissance survey of the power possibilities of the river system was made by a field party of the Manitoba Hydrometric Survey. A profile of the river was made by this party.

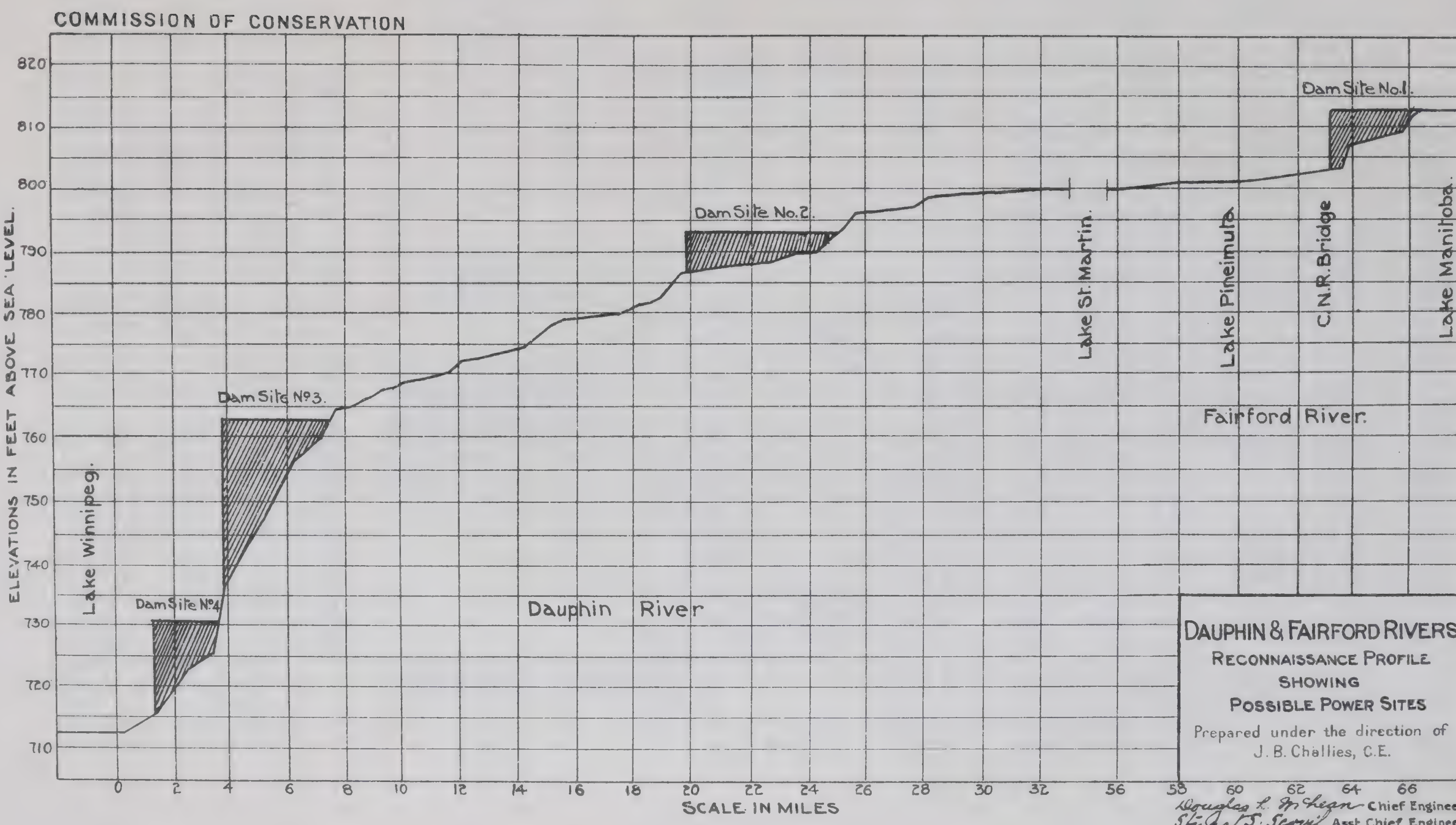
Precipitation in this drainage basin is estimated to be 18 or 19 inches per annum. Records over very short periods have been made at a few places in the district and the above estimate has been based upon them.

During the winter of 1915, a low flow of 3,400 second-feet was recorded. While this figure is being used for the computation of possible power, it should be borne in mind that it is subject to revision when more complete data are obtained.

Storage Possibilities

In view of the immense lake area in the lower reaches of the watershed, it should be possible to obtain practically a complete regulation of the flow. An estimate of the storage possibilities on lake Winnipegosis and of the resulting increase in flow during low periods, has been made with relation to the Waterhen river and Meadow portage.

Lake Manitoba is said to vary ordinarily from one foot above to one foot below its mean level, giving a total range of two feet. Assuming that such a range could be utilized for storage purposes, the following table gives the various rates of draught available from such a storage fully utilized during a period of either three months, six months or a year:—


COMMISSION OF CONSERVATION
ELEVATIONS IN FEET ABOVE SEA LEVEL.
820
810
800
790
780
770
760
750
740
730
720
710
Lake Winnipeg.
Dam Site No.4
Dam Site No.3.
Dam Site No.2.
Dam Site No.1.
Dauphin River
Lake St. Martin.
Lake Pineimuta.
C.N.R. Bridge
Lake Manitoba.
Fairford River.
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 56 58 60 62 64 66
SCALE IN MILES
DAUPHIN & FAIRFORD RIVERS
RECONNAISSANCE PROFILE
SHOWING
POSSIBLE POWER SITES
Prepared under the direction of
J. B. Challies, C.E.
Douglas L. McLean Chief Engineer
Stuart S. Scovil Asst. Chief Engineer

Depth of storage	Storage in thousands of cubic feet	Rate of draught in second-feet		
		Period, 3 mos.	Period, 6 mos.	Period, 1 year
1 foot	47,700	6,048	3,024	1,512
2 feet	95,400	12,096	6,048	3,024

Water-power Concentrations

Possible power concentrations on the rivers are shown on the profile facing page 66. An estimate of the power available at these sites is given in the following table. The power has been computed at 80 per cent efficiency on an estimated low flow of 3,400 second-feet, no estimate having been made respecting the additional power available through storage:—

Power site	Head in feet	Estimated horse-power at 80 per cent efficiency; low flow of 3,400 second-feet
No. 1	8	2,500
No. 2	6.5	2,000
No. 3	28	8,700
No. 4	16	5,000
Total horse-power		18,200

DISCHARGE MEASUREMENTS OF FAIRFORD RIVER AT FAIRFORD

Date	Discharge	Date	Discharge
		1914	Sec. ft.
1913	Sec. ft.	January 6	6,129
June 28	7,849	January 28	5,953
July 31	6,897	March 31	5,359
August 29	8,341	April 20	5,822
October 11	7,083	August 6	5,559
December 6	8,886	August 7	5,115
April 24	7,345	August 8	6,432
May 15	7,527	August 10	4,916
August 14	7,475	September 15	6,059
		December 19	3,647
		December 21	3,412

Waterhen River and Meadow Portage

The Waterhen river flows out of the southerly portion of lake Winnipegosis and discharges into the north end of lake Manitoba. Issuing from Long reach of lake Winnipegosis, it flows in a northerly direction, a distance of some eight miles, to Waterhen lake, thence, 18 miles in a southerly direction to lake Manitoba.

At the outlet of lake Winnipegosis, the drainage basin of the Waterhen has an area of 21,200 square miles, and comprises that portion of Manitoba lying between Winnipegosis and the highlands

of the Porcupine, Riding and Duck mountains. Westward from lake Winnipegosis to the mountains, the basin is a slightly undulating plain, with a gradual upward slope, which, for the most part, has an overlying soil of clay, with occasional outcrops of rock. In the vicinity of the mountains, the country becomes rugged and rises very abruptly. This highland, containing the headwaters of the drainage, is largely covered with a growth of pine and spruce. The main streams tributary to lake Winnipegosis, heading in this district, are the Red Deer, Swan and Valley rivers. While there are several large lakes in the lower portion of the drainage, such as Winnipegosis, Red Deer, Swan and Dauphin, the numerous lakes at the headwaters are very small.

From lake Winnipegosis to Waterhen lake, there are two distinct river channels; from the latter to lake Manitoba, the river flows in one channel only.

Low and Marshy Banks

In both the upper channels, the river flows between low, marshy banks, which extend back some 1,200 feet to the timber line, where the banks reach an elevation of from three to four feet above the ordinary level. Much of the intervening space between river and timber line is covered with water, and growths of reeds extend far out into the stream. The soil, to a depth of one foot, is light and sandy, but underlying this is a stratum of light blue clay mixed with gravel. From Waterhen lake to within a few miles of lake Manitoba, the banks are slightly higher and drier, and, from surface indications, are composed of the same soil. In the vicinity of lake Manitoba they are low and marshy.

The width of the main Waterhen river averages about 600 feet, except in the vicinity of the lakes where it increases to approximately a mile. The smaller channel, or Little Waterhen, has an average width of approximately 200 feet. The beds of both rivers are composed of gravel, strewn in some places with large boulders making navigation very difficult in the reach below Waterhen lake. Meadow land borders the river for almost its entire length. Timber is plentiful but consists almost entirely of poplar, with occasional spruce and birch.

Precipitation.—No definite information relating to the whole drainage basin precipitation is available. Records show a mean annual precipitation at Russell of 16.4 inches for a period of nine years, and of 17.8 inches at Minnedosa for a period of 32 years, but both localities are situated slightly to the south of the basin. As somewhat similar physical conditions apply to the upper drainage of the Waterhen and to these two points, it may be assumed that the precipitation is of like amount.

Discharge Measurements.—In the summer of 1881, a discharge measurement of the Waterhen river was made by Thomas Guerin, C.E. No further measurements appear to have been made until 1913, when one was made by the Manitoba Hydrometric Survey, at a section below Waterhen lake, showing a discharge of 8,474 second-feet. Owing to the inaccessibility of this portion of the river, no regular gauging station has been maintained. In the absence of more reliable data, an estimated low flow of 3,000 second-feet has been based on measurements made on the Fairford river by the Manitoba Hydrometric Survey. While this estimate is used for computing the power possibilities it is only an estimate, and is subject to revision.

Meadow Portage and Power Possibilities

The power possibilities in the Waterhen river itself do not offer any very attractive features, but its waters can be diverted across the narrow neck of land separating lake Winnipegosis from lake Manitoba. This strip of land, lying at the southwest corner of the former lake, has, in the vicinity of Meadow portage, a minimum width of some 9,400 feet. The summit elevation is approximately six feet above lake Winnipegosis, and the surface soil is composed of a light grey, calcareous clay, containing many limestone pebbles. Investigations made at the summit show hardpan at a depth of four feet, while, adjacent to the lakes, clay constitutes the underlying soil.

Construction of Canal Advocated

At various times the construction of a canal between the two lakes has been advocated for navigation purposes, and, were this undertaking proceeded with, the development of power in conjunction with the canal would be an important factor.

The Waterhen river and Meadow portage are both accessible in summer by boat, and by waggon from the town of Winnipegosis, at the southern end of lake Winnipegosis.

Except Waterhen Indian reserve, which lies near the southern end of Waterhen lake, there are no important settlements in the immediate vicinity. The country around Meadow portage has been surveyed and is partially settled. In 1889, the Geological Survey made a geological examination of the district, including the Waterhen river. Prior to 1909, the Dominion Department of Public Works made a survey of Meadow portage, and, in 1909, made further investigations. In the summer of 1913, a reconnaissance survey of Meadow portage was made by the Manitoba Hydrometric Survey, with Mr. D. B. Gow in charge of the field party. At the same time, as it would be necessary to divert the water for any complete development in the vicinity of Meadow portage, investigations of dam sites on the upper Waterhen river were made.

Head Available

The difference in elevation between the two lakes on August 26, 1913, as determined by the Manitoba Hydrometric Survey, was 18·6 feet. The water in both lakes at the time was stated locally to be at a high stage. As published in the *Geological Survey Report* of 1890-91, the difference in elevation in 1873 was found by Mr. H. B. Smith, C.E., to be 18.73 feet, and later, in 1889, a determination of 17.4 feet was made by G. A. Bayne, C.E.

Owing to storms on the lakes, considerable variation in this descent is quite probable. It is stated that a severe storm from the northwest may raise the waters three feet at the southerly end of lake Winnipegosis. Evidences of such an effect were noted by the Manitoba Hydrometric Survey after a severe storm. At the same time, a lowering of the northern waters of lake Manitoba occurs, but within a decidedly narrower range than in the upper lakes.

As stated previously, a low flow of 3,000 second-feet has been assumed for the Waterhen river. This, together with an approximate head of 15 feet (both figures are subject to revision), would, on a basis of 80 per cent efficiency, show a power possibility of 4,080 horse-power.

Storage Possibilities

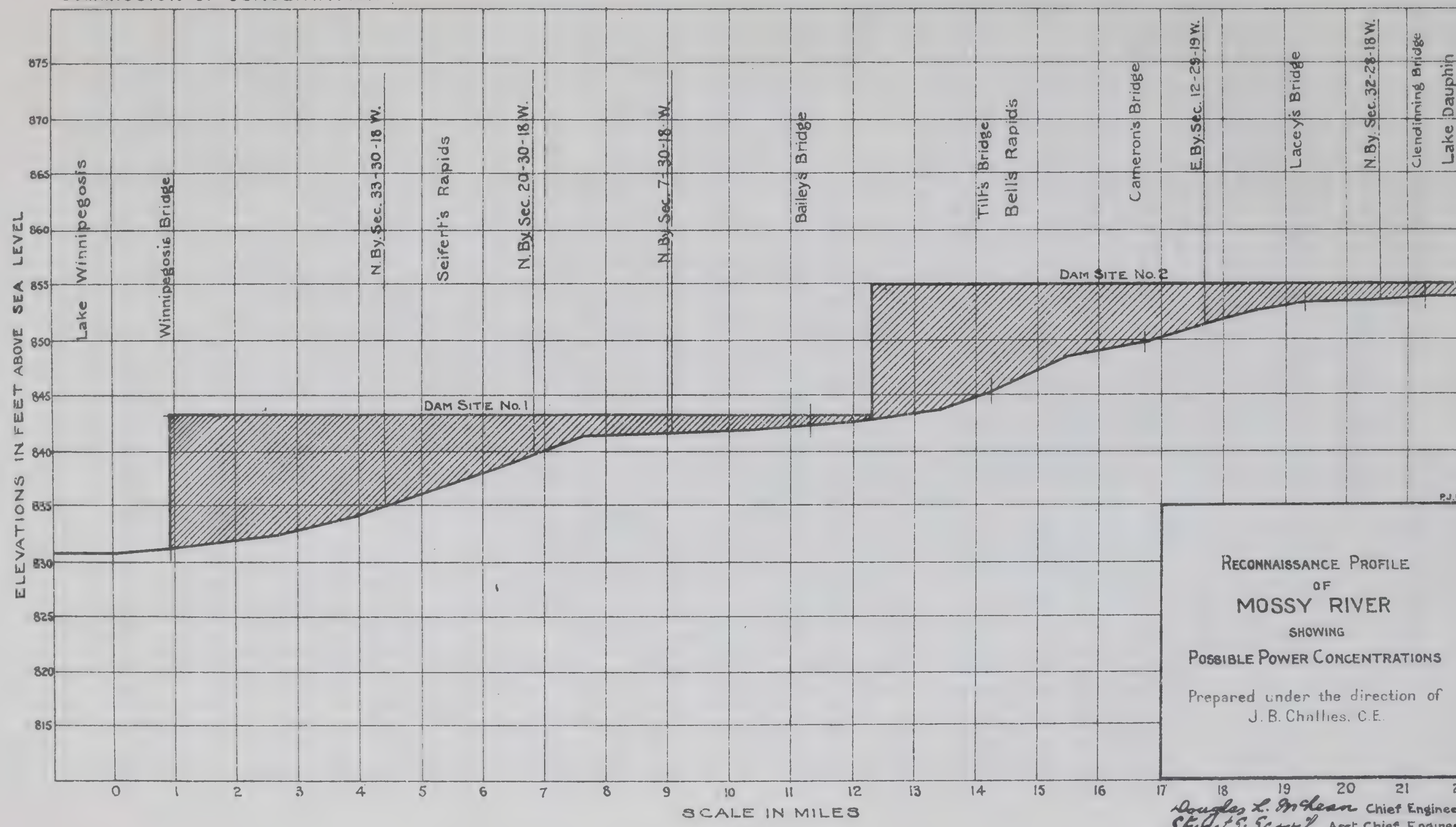
Lake Winnipegosis, which acts as the collecting basin for the entire drainage area, offers immense storage possibilities. It has an area, exclusive of islands, of approximately 2,000 square miles. While storage is possible, the effect of any raising of the waters would have to be considered with reference to adjacent low-lying areas. The following table has been computed to show the possibilities of additional flow and power from such storage under the following headings: (*a*) the flow in cubic feet per second for a storage utilized during a period of six months; (*b*) the power available from this flow based on a 15-foot head at 80 per cent efficiency; (*c*) the flow in cubic feet per second for a storage utilized for one year; (*d*) the power available based on the same conditions as in (*b*) :—

Depth of storage in feet	(*a*) Flow in second-feet for six mos.	(*b*) Horse-power	(*c*) Flow in second-feet one year	(*d*) Horse-power
1	3,536	4,814	1,768	2,407
2	7,072	9,628	3,536	4,814

DISCHARGE MEASUREMENT OF WATERHEN RIVER, FOUR MILES FROM LAKE MANITOBA

Date	Mean velocity	Discharge
1913	Ft. per sec.	Sec.-ft.
August 26	2.79	8,474

COMMISSION OF CONSERVATION



Mossy River

Mossy river is approximately 21 miles in length and discharges into the southerly end of lake Winnipegosis. Heading in the extreme northerly portion of lake Dauphin, it flows westward for two miles, then bends and flows in a northerly direction to the mouth.

With the exception of the Fork and Fishing rivers, which enter the Mossy from the west, the drainage of the basin is collected by lake Dauphin. Discharging into this lake are the Valley, Turtle, Ochre, Wilson and Vermilion rivers. These streams, which head in many small lakes and muskegs in the Riding and Duck mountains, flow in a general easterly course to the lake. The upper watershed in the mountains comprises a hilly or rolling country, which is well timbered, while the lower and greater portion of the basin is undulating prairie, covered in many places with a growth of willows.

Banks of River

The banks of the Mossy vary in height from 4 to 14 feet and are composed of blue or yellow clay, overlying a bed of fine gravel. Approximately one and one-half miles above lake Winnipegosis an outcrop of limestone crosses the bed of the river. Here, for a distance of 100 feet along the left bank, a vertical face of rock extends some six feet above the ordinary river level. Below this outcrop the banks become low and marshy. At various points along the river, dredged material from the bed has been dumped along shore, forming an irregular bank.

The Mossy varies in width from 120 to 200 feet, with an average of 160 feet. The bed of the stream is composed of sand and gravel, with numerous boulders occurring in certain localities. The channel has been improved by dredging and by the removal of boulders, practically eliminating all rapids. Owing to sand bars, very shallow water occurs at the outlet from lake Dauphin, and also at its mouth.

High water usually occurs in April and early in May at the time of the spring break-up. Heavy rains on the headwaters also cause high water during later periods of the year. It is stated that, in 1902, extreme high water occurred, being six feet higher than the ordinary level. In July, 1913, the water was again high, due to prolonged heavy rains, but did not reach within four feet of the extreme of 1902. Low water usually occurs in February. It is stated locally that, for the first three miles below lake Dauphin, the river does not freeze over; farther downstream the surface freezes, in some places to a depth of two feet or more. It is also reported that, since the improvements to the channel, the ice breaks up in the spring without the formation of ice jams.

Winnipegosis, the terminus of the Winnipegosis branch of the Canadian Northern railway, is situated at the mouth of the river. Southerly from this town, for a distance of 14 miles, to Fork River, the railway is never more than one and one-half miles distant from the river. The town of Dauphin, which is the central point of the district, is some 40 miles from Winnipegosis. Several bridges, accessible by numerous roads, cross the river at various points. The stream is navigable by small craft, but is not now used for transportation.

To lower lake Dauphin, the Department of Public Works dredged the river in 1909-12. In 1905, D. A. Keizer, C.E., surveyed and reported on a possible power site situated one-half mile above Winnipegosis. During the summer of 1913, a reconnaissance investigation of the power possibilities of the river was made by a field party of the Manitoba Hydrometric Survey.

Precipitation.—Although no adequate records of precipitation are available for the district, it is estimated that the mean annual rainfall is approximately 18 inches; the estimate is based on records in adjoining drainage basins of practically the same physical features.

Storage Possibilities

Lake Dauphin, with an area of 196 square miles, is the collecting basin of all drainage carried by the Mossy river and preliminary investigations indicate that it would be possible to obtain three feet storage on it. At the same time, it would be necessary to consider the effect of such storage, particularly as the dredging and improvements to the river channel were carried on with the object of *lowering* the level of the lake and giving better drainage to the low-lying lands adjacent. The following table gives an estimate of the flow available from storage on the lake, under the following headings,—(*a*) The capacity of reservoir per foot depth of storage; (*b*) the rate of draught available for a storage extending over a period of six months; (*c*) the rate of draught available for a storage extending over one year:—

Depth of storage	Storage in millions of cubic feet	Flow in cubic feet per second	
		Period six months	Period one year
	(*a*)	(*b*)	(*c*)
1 foot	5,464	346	173
2 feet	10,928	692	346

Power Possibilities

Discharge measurements taken during 1913, 1914 and 1915 show a minimum mean monthly flow of 65 second-feet. Based on this amount, which is subject to verification or revision as future records are obtained, the following table gives the estimated available horse-power at two possible power

sites, as shown on profile facing page 72. The estimates have been based on 80 per cent turbine efficiency. No estimate is made as to the additional power available through a regulation of the flow of the river, although such regulation would greatly increase the power possibilities:—

Power site	Head in feet	Estimated horse-power, based on 80 per cent efficiency; minimum flow of 65 second-feet
No. 1	10	59
No. 2	10	59
Total horse-power		118

DISCHARGE OF MOSSY RIVER, NEAR FISHING RIVER, MAN.†
(Drainage area 3,950 square miles.)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1913				
July (14-31)	1,710	1,435	1,536*	.39
August	1,435	1,080	1,214	.31
September	1,105	329	918	.23
October	868	410	693	.18
1914				
January	620	560	592*	.150
February	629	522	567*	.144
March	541	485	513*	.130
April	505	460	490	.124
May	1,175	493	696	.176
June	955	572	715	.181
July	560	420	522	.132
1915				
January			150*	.038
February			160*	.041
March	754		300*	.076
April	581	168	259	.066
May	207	117	179	.045
June	224	137	177	.045
July	327	145	206	.052
August	172	69	126	.032
September	134	53	99	.025
October	163	31	109	.028
November			80*	.020
December			65*	.016

* Estimated.

† Measurements made at Manitoba Hydrometric Survey station.

Valley River

The Valley river, so called because it flows in the valley between the Riding and Duck mountains, rises in Singoosh lake, in the northerly portion of the Duck mountains. Thence it flows in a southwesterly direction to East Angling lake, which also receives the drainage of Laurie and North Angling lakes from the north. From East Angling lake the river flows southerly a distance of approximately 16 miles, and thence in an easterly direction to lake Dauphin. Near this easterly bend, Short creek, which rises in Riding Mountain forest reserve and drains several small lakes, enters it from the west. Below this, the main drainage to the river enters from the north, the chief tributary being Drifting river, which joins the Valley three miles west of Valley River station, on the Canadian Northern railway.

The banks vary in height, from 15 to 85 feet, while the width of the bottom land ranges from 700 to 2,000 feet, widening occasionally to 3,000 feet. At ordinary summer stage the river has a width of from 100 to 200 feet; the banks are composed of yellow clay, overlying a bed of gravel and boulders. Investigations carried on at several points in that portion of the river lying between Gilbert Plains and Valley River station have shown a depth of clay, varying from 6 to 30 feet, overlying the gravel strata. The bed of the river is of gravel, strewn with boulders.

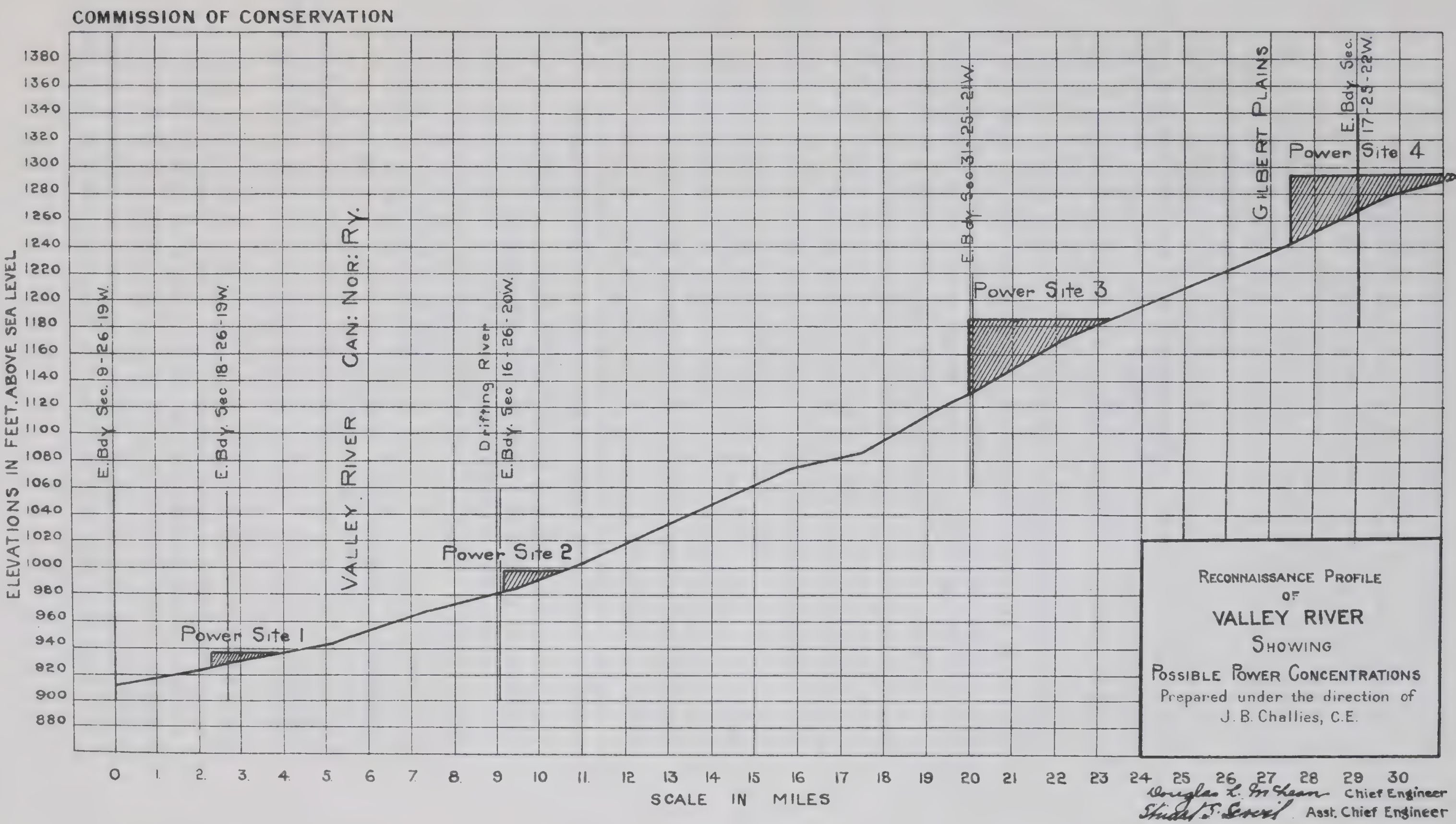
In the upper watershed, there is a considerable growth of valuable timber, comprising spruce, jackpine and poplar. In the lower section, the valley bottom and banks are covered with a growth of scrub oak, poplar and briar. Very little clearing has been done in the immediate vicinity of the river, but grain growing and mixed farming are carried on extensively in the adjacent country.

High water usually occurs at the time of the spring break-up in April. The river, however, is subject to extreme fluctuations in the open water season, heavy rains in the headwaters causing floods in the lower valleys. Low water occurs in the autumn and winter months.

Traverses Well Settled District

Owing to shoals and rapids, navigation is impossible except in rowboat and canoe. The river is accessible by many roads, and is also crossed by the Canadian Northern railway at Valley River, Grandview and Strevel; nowhere between these crossings is it more than five miles distant from the railway.

The country adjacent to the Valley river is well settled and contains several thriving villages, such as Gilbert Plains, Grandview and Valley River. The town of Dauphin, the centre of this agricultural district, is six miles distant from the river.


COMMISSION OF CONSERVATION
ELEVATIONS IN FEET ABOVE SEA LEVEL
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1140
1120
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1080
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960
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920
900
880
E. Bdy. Sec. 9-26-19W.
E. Bdy. Sec. 18-26-19W.
VALLEY RIVER
CAN: NOR: RY.
Drifting River
E. Bdy. Sec. 16-26-20W.
E. Bdy. Sec. 31-25-21W.
GILBERT PLAINS
E. Bdy. Sec. 17-25-22W.
Power Site 1
Power Site 2
Power Site 3
Power Site 4
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
SCALE IN MILES
RECONNAISSANCE PROFILE
OF
VALLEY RIVER
SHOWING
POSSIBLE POWER CONCENTRATIONS
Prepared under the direction of
J. B. Challies, C.E.
Douglas L. McLean Chief Engineer
Stuart S. Scovil Asst. Chief Engineer

Surveys of the River

In 1887, the Geological Survey made a survey of the river, from lake Dauphin to Angling lake. In 1913, a reconnaissance survey of the power possibilities was undertaken, and a preliminary investigation of the storage possibilities of the upper watershed was made by Mr. D. B. Gow, of the Manitoba Hydrometric Survey.

Rainfall.—Rainfall records, extending over a sufficient period of time, are not available for this drainage area. Records at Minnedosa, which lies to the southeast of the basin, but to which, to a great extent, the same physical conditions apply, show a mean annual rainfall of 18 inches for a period of 32 years.

Discharge Measurements.—A summary of discharges for the year ending October 31, 1913, shows a low-water flow of 20 second-feet occurring in January, February and March. During March, 1915, there was practically no flow in the river. The maximum flow recorded at the time of the spring break-up in 1913 was 2,760 second-feet, but, during July, the river reached flood stage, due to exceptionally heavy rains, and showed a maximum discharge of some 3,500 second-feet.

Storage Possibilities

Definite information is not available with reference to all the lakes lying in the headwaters of the drainage. A reconnaissance investigation of the Angling lakes shows it to be possible to obtain five feet storage on North Angling lake and three feet storage on East Angling lake, the latter being a collecting basin for the major portion of the upper drainage. In the case of the former, the topographical features of the shores and outlet would permit of greater depth of storage, but the depth, as given, has been estimated as being all that the tributary run-off would require. This same feature applies to Singoosh lake, which has not been investigated but is stated locally to be capable of a storage of ten feet. Further storage might be obtained on other small lakes; the following table gives an estimate of that available on the three above-mentioned lakes:—

Lake	Area in acres	Depth of storage in feet	Storage in cubic feet
East Angling	288	3	37,700,000
North Angling	230	5	50,100,000
Singoosh	2,880	3	376,500,000
Total			464,300,000

As there was no flow in the river during certain winter months of 1914 and 1915, the estimated power, based on 80 per cent. efficiency, has been computed for a low open water season flow of 10 second-feet. Under these conditions, sites No. 1 and No. 2 would each give 17 h.p.

under 19 feet of head; No. 3 would give 50 h.p. under 56 feet of head, while 47 h.p. would be available at No. 4 under a head of 52 feet.

MONTHLY DISCHARGE OF VALLEY RIVER, AT VALLEY RIVER, MAN.
(Drainage area, 1,028 square miles)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1912				
November			150*	.146
December			50*	.048
1913				
January			20*	.019
February			20*	.019
March			20*	.019
April (3-30)	2,760	445	1,380*	1.34
May	996	172	611	.594
June	630	146	250	.243
July	3,540	71	1,410	1.37
August	495	40	262	.255
September	271	38	102	.10
October	81	59	70*	.068
1914				
January			4*	.004
February			0*	
March			2*	.002
April			185*	.180
May	2,340	248	1,080	1.051
June	1,750	68	285	.277
July	196	14	68	.066
August	30	3	12	.012
September	47	5	16	.016
October	33	5	20	.019
November			12*	.012
December			8*	.008
1915				
April	206	*	80*	.078
May	101	30	53	.052
June	119	31	76	.074
July	211	33	90	.089
August	32	2	9	.009
September	43	2	21	.020
October	49	32	38	.039
November	46	0*	20*	.020

* Estimated.

Swan River

The Swan river, situated in central western Manitoba, rises to the west of the Porcupine mountain and flows in a southerly direction for 50 miles. Here it turns to the northeast, through the valley between the Porcupine and Duck mountains, and discharges into Swan lake. Between the Duck and Porcupine mountains, it flows in a wide, deep valley. From Swan lake to the point at which it loops around the

Porcupine mountains, it receives practically all its drainage from the south, including many small tributaries heading in Duck mountain. To the north, the drainage area is confined by Woody river, which parallels the Swan. Above the loop, the basin expands, with many small tributaries entering from east and west. Many springs are reported to exist in the vicinity of the river, but the lakes of the basin are small and few in number.

Nature of Bed and Banks

The valley and banks are, to a great extent, composed of alluvial sand or clay. It is stated that, in the upper portion of the valley, outcroppings of grey clay, shale and sandstone occur along the river. The stream has an average width of 150 feet, with banks ranging from 10 to 50 feet in height, and a bed composed of gravel and clay, with boulders at many points.

The latter part of April is usually the period of high water, while February is the low-water month. In 1913, a range of some four feet was recorded between the two extremes.

Many beds of boulders in the river render navigation impossible. The river is accessible, however, by old trails, and is crossed by the Canadian Northern railway at the town of Swan River. A branch line of this railway parallels the river for a considerable distance above the town.

An Agricultural District

The country is essentially an agricultural district and is well settled. The town of Swan River is the commercial centre, though there are many smaller and less important settlements.

In many portions of the mountain country, there is an overgrowth of timber, while, in the Swan River valley, the country is more open. On the rich meadow land of this district, grain growing is carried on extensively.

In 1909, Messrs. Pratt & Ross, hydraulic engineers, investigated the power possibilities of the river in the vicinity of the town of Swan River, and reported upon a possible power development.

Precipitation.—No complete records of precipitation are available, but it is estimated that the annual mean for the basin is approximately 19 inches.

Water-power Possibilities

No field survey has as yet been made of its power possibilities, though it is known that considerable descent occurs throughout its course. At the mouth of Snake creek, some 18 miles west of the Manitoba boundary, the elevation of the river bed, as obtained from preliminary lines of the Canadian Pacific railway, is 1,390 feet above sea level, while Swan

lake is at an elevation of 849 feet. This would indicate a fall of 541 feet in an approximate distance of 100 miles.

During certain winter months of 1915 there was no flow in the river, but it is estimated that about 25 second-feet would be available during the open water season. Assuming an efficiency of 80 per cent, this flow would represent 23 horse-power for every 10 feet of head.

MONTHLY DISCHARGE OF SWAN RIVER, NEAR SWAN RIVER, MAN. MEASUREMENTS BY MAN. HYDRO. SURVEY
(Drainage area 1,215 square miles.)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1912				
November			400*	.329
December			100*	.082
1913				
January			70*	.058
February			50*	.041
March			50*	.041
April (12-30)	4,838		2,180*	1.79
May	1,317	793	1,017	.838
June	765	228	474	.390
July	3,702	606	1,820	1.50
August	865	296	531	.437
September	360	151	245	.202
October	232	109	160	.13
1914				
January			40*	.033
February			40*	.033
March			30*	.025
April			1,200*	.988
May	3,975	568	1,570	1.293
June	520	94	229	.188
July	91	18	51	.042
August	31	11	22	.018
September	44	22	32	.026
October	70	25	50	.041
November			40*	.033
December			20*	.016
1915				
March			14*	.011
April	1,142		400*	.329
May	132	50	81	.067
June	135	49	96	.079
July	420	98	202	.166
August	153	32	74	.061
September	61	32	39	.032
October	62	53	60	.049
November	62		40*	.033
December			10*	.008

* Estimated.

Red Deer River

The Red Deer river rises in township 44, range 19, west of the second meridian, some 15 miles south of Melfort, Sask. It flows in an easterly direction, to Red Deer lake—area, 100 square miles—and thence into lake Winnipegosis.

Like the Swan river, the Red Deer flows in a deep, wide valley of glacial origin, though of greater extent than the valley of the former. In the upper portion of the watershed, the drainage is collected by several tributary streams, including the Fir, Etomami, Pipestone and Barrier rivers, which drain a large tract of country and head in many small lakes and swamps. A forest of spruce and poplar covers a great portion of this district. In the lower reaches, the drainage area to the north is somewhat confined, due to a parallel river system.

Nature of Bed and Banks

While rock outcrops occur at a few places in the lower reaches of the river, the bed and banks are, for the greater part, composed of sand, gravel and clay, this latter constituent composing the greater portion of the Red Deer valley; the bed is also strewn with boulders at many places. The width of the river is stated to vary from 150 to 250 feet, and the banks range from 15 to 50 feet in height.

Under ordinary conditions high water occurs in the latter part of April or early in May and low water occurs in the winter months, with a range of some four to five feet between the two periods. In the spring of 1913, due to ice jams on the river, an extreme range of 14 feet was noted at one point.

The Canadian Northern railway crosses the river at Erwood, some 30 miles west of Red Deer lake. For a considerable distance above this point the railway is situated within the vicinity of the river. A spur line touches Red Deer lake at Barrows.

Precipitation.—Only meagre records of precipitation are available, but, from these, it is apparent that the mean annual rainfall is about 15 inches.

Storage Possibilities and Water-power

No field investigation has been made of the storage possibilities of this river. As many small lakes are situated in the upper drainage, storage of sufficient extent to greatly increase the low flow of the river should be available. Red Deer lake, with an area of 100 square miles, offers facilities for regulation of the flow below its outlet. The following table gives the flow available from a storage of one or two feet on this lake. The rates of draught in second-feet are computed for a storage used in a six-months or a year period:—

Depth of storage	Capacity in billion cu. ft.	Rate of draught, 6 months	Rate of draught, 1 year
1 foot	2,787.84	178	89
2 feet	5,575.68	356	178

One of its tributaries, Pipestone creek, rises in a country whose elevation is approximately 2,000 feet above sea level, while lake Winnipegosis has an elevation of 832 feet; thus there is a descent of more than 1,100 feet between the headwaters and the mouth. Considerable descent occurs in Manitoba; the fall between Red Deer lake and lake Winnipegosis is stated by the Geological Survey to be 43 feet. While field investigations of the power possibilities of the river have not been made, if a minimum mean monthly flow of 80 second-feet is assumed for the period from April to October, every 10 feet of head would represent 73 horse-power based on 80 per cent efficiency. No winter estimates are given, as at times the flow dwindles to nil.

MONTHLY DISCHARGE OF RED DEER RIVER, NEAR HUDSON BAY JUNCTION, MAN.†

(Drainage area, 4,900 square miles)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1913				
July			*3,480	.710
August	2,521	1,382	1,993	.406
September	1,451	651	956	.195
October	625	363	530	.108
1914				
January			*70	.014
February			*50	.010
March			*30	.006
April			*1,800	.367
May	3,925	1,750	3,000	.612
June	2,150	499	1,050	.214
July	451	118	268	.055
August	118	67	78	.016
September	94	70	80	.016
October	91	70	83	.017
November	91		*60	.012
December			*25	.005
1915				
January			*1	.000
February			*0	.000
March			*1	.000
April			*275	.056
May	193	93	133	.027
June	230	85	152	.031
July	1,802	230	711	.145
August	470	83	161	.033
September	116	68	81	.017
October	95	73	80	.016
November			*36	.007
December			*5	.001

†Based upon gaugings by Manitoba Hydrometric Survey. *Estimated.

CHAPTER IV

Eastern Tributaries of Lake Winnipeg*

METERING STATIONS ESTABLISHED BY THE MANITOBA HYDROMETRIC SURVEY

Name of River	Situation	When established
Brokenhead	Sinnot	May, 1912
Manigotagan	Wood fall	Dec., 1912

Brokenhead River

The Brokenhead river flows into the south-easterly section of lake Winnipeg. It drains a long, narrow strip of land lying between the watersheds of the Winnipeg and Whitemouth rivers on the east, and of the Red river on the west.

It drains 910 square miles; its greatest width is 22 miles, and its total length 75 miles. The greater part of this area is low lying and marshy land, though some reclamation work has been done along the banks in the lower reaches, and the land is under cultivation. In the upper basin, much of the land is swampy and cannot be cultivated until drained.

The bed and banks are composed of sandy clay, intermixed in some sections with large boulders. The banks as a rule are low and rise from five to ten feet above the bed of the stream.

Rainfall.—From rainfall records, it is found that the mean annual precipitation in the drainage basin of the river is 22 inches.

Power Possibilities

No survey work has been done on this river with respect to power possibilities and, considering the nature of the adjacent country, it is doubtful if there are any power sites on the river. If any should be discovered, their development would necessarily be for operation only during the open season, as it has been found that the flow is liable to be completely

* The portion of this chapter relating to the Brokenhead, Manigotagan, Bloodvein, Poplar, Big Black and Bélanger rivers, has been prepared under the direction of Mr. J. B. Challies, Superintendent of the Water Power branch of the Department of the Interior. The Pigeon and Berens rivers have been covered by reconnaissance undertaken by the Commission of Conservation.

cut off during the winter months. The descent in the river from the village of Sinnot to lake Winnipeg, a distance of approximately 40 miles, is 72 feet, or 1·8 feet per mile.

No estimates for power are given as, while the flow is often reduced to nil during the winter, it is not always dependable during the open season, as shown by a mean monthly flow of only 4 second-feet in September, 1915.

MONTHLY DISCHARGE OF BROKENHEAD RIVER, NEAR SINNOT, MAN.†

(Drainage area 530 square miles.)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1912				
June (8-30)	573	32	245*	.46
July	352	16	113	.21
August	203	26	57	.11
September	758	75	410	.77
October	690	304	475	.90
November	398	160	286*	.54
December			10*	.02
1913				
January			0*	
February			0*	
March			0*	
April			200*	.38
May	364	92	209	.39
June	400	16	89*	.17
July	448	16	180	.34
August	388	8	185	.35
September	326	61	166	.31
October	208	38	114	.21
1914				
April	455		267*	.504
May	323	145	237	.447
June	908	167	475	.896
July	1,043	63	467	.881
August	258	52	86	.162
September	136	61	85	.160
October	376	80	227	.428
November	234	44	137	.258
December	44*	13	28	.053
1915				
January			6*	.011
February			4*	.008
March			3*	.006
April			285*	.538
May	841	181	521	.983
June	295	122	227	.428
July	234	55	127	.240
August	51	2	14	.026
September	26	2	4	.008
October	95	32	65	.123
November			40*	.076
December			15*	.028
Year	841	*	109	.206

†Based upon gaugings by Manitoba Hydrometric Survey.

*Estimated.

Manigotagan River

The Manigotagan river discharges into lake Winnipeg on the east shore, about 50 miles north of Fort Alexander, and almost directly opposite the centre of Big island. From Muskrat lake to its mouth the general bearing of the river is west 30 degrees north. The flow into Muskrat lake is said to come from the northeast.

While the upper reaches of the watershed have not yet been explored, it is stated that considerable drainage comes in beyond Long lake. From Long lake to Turtle lake the basin expands and includes the Caribou, Muskrat, Moose, Bullfrog and many other small lakes. From Turtle lake to the river mouth, there are a number of small creeks draining the adjoining swamps and muskegs. All of these are small and sluggish at their entrance to the river.

General Description of Banks and Bed

At the mouth of the river the clay banks form good agricultural land, partially cleared and occupied by settlers. Even here, however, rock outcrops are found at several places. Above Wood fall the banks are very irregular, and, in most cases, rocky, ranging from 2 feet to 60 or 70 feet in height, being broken by many valleys, which lead back to muskegs or swamps. In the upper reaches, ranges of hills skirt the river on either side.

For the first 25 miles the river has an average width of about 175 feet, contracting at the many rapids and falls; three or four miles below Turtle lake the channel widens, and from that point to Muskrat lake, there are many portions with a width of from 700 to 900 feet. Below each rapid a large, circular pool, from 500 to 800 feet in diameter, constitutes a noticeable feature. The bed is covered with black muck, except at falls and rapids, where boulders and rock form the bed.

Almost the entire drainage area is covered with inferior timber, which includes a plentiful supply of poplar and spruce, together with jack pine, birch, oak and balsam. In the vicinity of Muskrat lake and beyond Moose lake, there is a fringe of valuable spruce bordering the lakes, but this does not appear to extend far back into the interior. In the immediate vicinity of the river, valuable timber has been removed, but fire does not seem to have been responsible for depleting the supply, as is often found where first cutting has been made.

High water usually occurs in June, when a height of three and one-half or four feet above the low water mark has been noticed. Low water occurs in the autumn and in March or April.

Small steamers can navigate to the foot of Wood fall, but beyond this point, canoes are the only means of transportation. A winter road has been cut through from Manigotagan settlement to Muskrat lake. This road crosses and re-crosses the river, and, consequently, is of use only during the winter months.

The only permanent settlement is at Manigotagan village, at the mouth of the river. At this point the Phoenix Brick, Tile and Lumber Co. has been making brick with a modern plant, and has also operated a saw mill.

Surveys of the River

In 1913, the Manitoba Hydrometric Survey made a reconnaissance of the river from Wood fall to Long lake.

Rainfall.—There are no rainfall records available for this drainage area, but it is estimated that a mean annual rainfall of some 21 inches might be expected.

Storage Possibilities and Water-powers

The run-off data on hand for 1913, taken as the lowest of the three during which records were taken, shows that a uniform flow of 150 second-feet could have been maintained had there been a storage reservoir capable of holding 1,450 million cubic feet of water. This amount could be obtained by using Muskrat lake as a storage basin. This lake has an area of 8.3 square miles, and it would be possible to store some 7.8 feet. This would give a storage capacity of 1,800 million cubic feet, thus providing ample storage.

The water-power sites on the river are shown on the profile facing page 86. The following tabulation shows possible power concentrations, under conditions of minimum flow and under regulated flow, based on the records of 1913, and gives the power at 80 per cent efficiency:—

No.	Name	Head	Estimated h.p., 80 per cent efficiency	
			Min. flow	Reg. flow
1	Wood fall	33	90	449
2	Poplar fall	8	22	109
3	1st rapid above Poplar fall	12	33	163
4	4th rapid above Poplar fall	30	82	408
5	3rd rapid above Cascade portage	12	33	163
6	6th rapid above	18	49	245
7	Charles fall	34	92	462
8	Turtle cascade	28	76	381
9	2nd rapid above	21	57	286
10	Caribou fall	27	74	368
	Total horse-power		608	3,034

Manigotagan River—Wood Fall

Manigotagan River—Rapid below Cascade Portage

MONTHLY DISCHARGE OF MANIGOTAGAN RIVER, ABOVE WOOD FALL†

(Drainage area, 375 square miles)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1913				
January			130*	.34
February			130*	.34
March			130*	.34
April			200*	.54
May	473	320	428	1.14
June	464	262	336	.89
July	352	143	207	.55
August	131	42	98	.26
September			80*	.21
October			60*	.16
November			40*	.11
December			30*	.08
1914				
February			40*	.107
March			40*	.107
April			80*	.213
May	265	109	183	.488
June	529	201	345	.920
July	617	201	424	1.131
August	201	109	139	.371
September	109	88	96	.256
October	375	115	239	.637
November			120*	.320
December			90*	.240
1915				
January			50*	.133
February			50*	.133
March		51	50*	.133
April	1,110		470*	1.253
May	1,066	692	811	2.163
June	626	340	510	1.360
July	340	153	257	.685
August	153	123	136	.363
September	145	111	124	.331
October	296	153	217	.579
November			360*	.960
December			180*	.480

†Based upon gaugings by Manitoba Hydrometric Survey.

*Estimated.

Bloodvein River

The Bloodvein river discharges into a bay on the east shore of lake Winnipeg and near the narrows. In the upper reaches, the river flows westerly, but, in the vicinity of lake Winnipeg, bends slightly to the north.

General Description of River and Basin

While little is known of the headwaters of the river, it is estimated that the drainage basin comprises an area of 3,000 square miles. The greater portion of the basin is rocky and of granitic formation, with the occasional occurrence of a light covering of clay. Several small tributary streams enter the Bloodvein from the north, and, in the upper watershed, the main river is divided into two branches. The northerly branch rises in Sasaginnigak lake, while the southerly branch is stated to extend to the height of land separating this drainage basin from that of the English river.

In the vicinity of the mouth of the river, which has an average width of 150 feet, the banks are composed of clay, and are about five feet in height. Some nine miles upstream the first rapid on the river occurs. A short distance above the rapid, the Little Bloodvein falls in. Thence, to the mouth of Turtle river, a distance of from 35 to 40 miles, there are many rapids and falls, some of which are reported to have considerable fall. The banks are rocky and low, replaced occasionally by marsh and muskeg, but some portions, composed of clay or clay and gravel overlying the rock outcrop, rise from 10 to 20 feet in height. It is reported that the country along the river is very rocky, with a very shallow covering of soil, and that the district presents the same general characteristics up to the junction of the North and South branches near Kowtunigan lake. The South branch rises in a region of which little is known, while the North branch again separates into two branches, both rising in the same lake. This lake, known as the Sasaginnigak lake, and stated to have an extreme length of about four miles and a width of about two, is dotted with numerous islands. Of the territory tributary to the lake little is known.

Navigation of this river is impossible except by canoe, and, even by this means, many portages are necessary. The mouth is easily reached during the summer months, as it is within a short distance of the route followed by steamers on lake Winnipeg.

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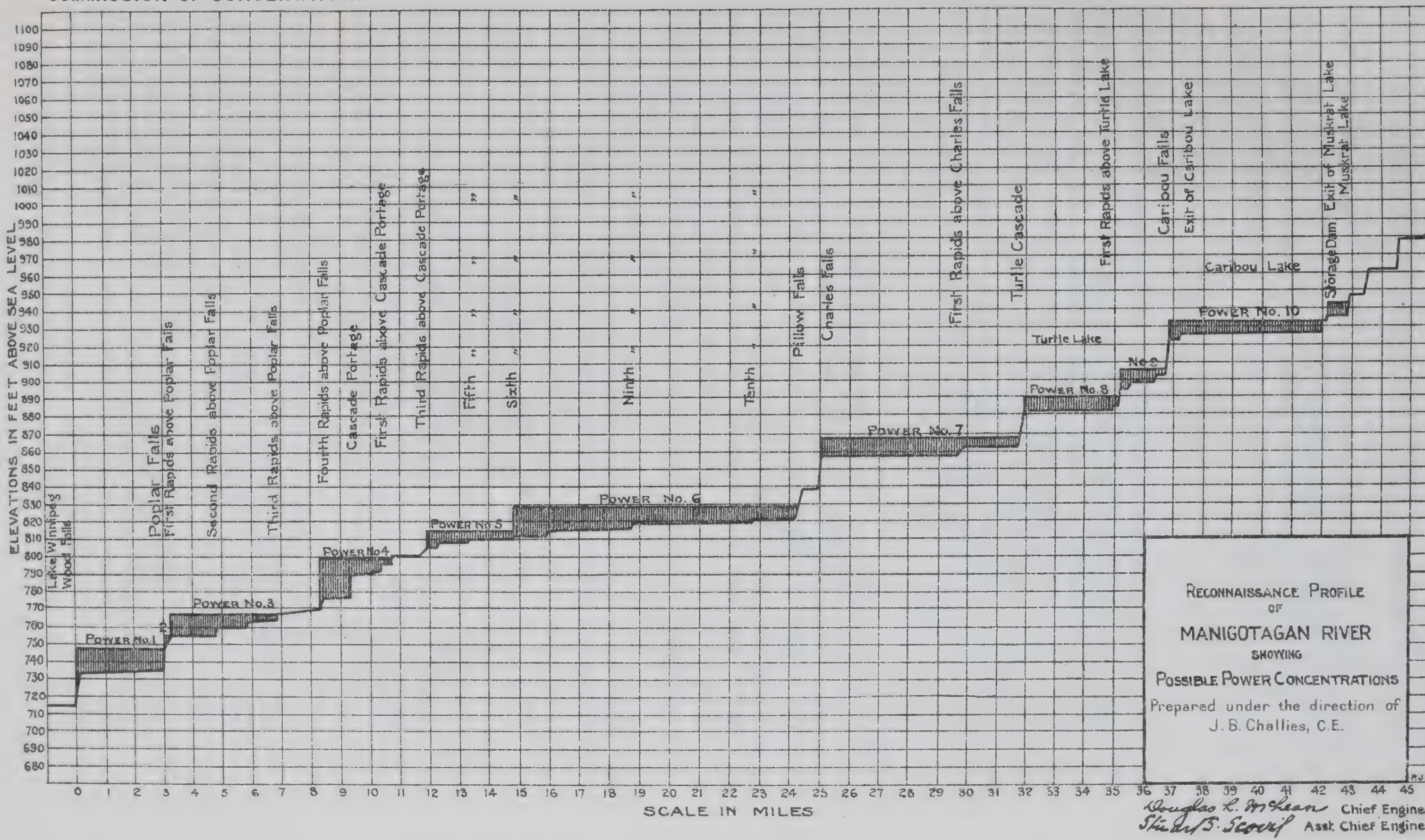


The adjoining country is rocky and many rapids occur throughout the extent of the river. The total descent between Sasaginnigak lake and the mouth, a distance of 69 miles, is reported as 150 feet. A discharge of 320 second-feet was recorded during the winter of 1915.

Pigeon River

Pigeon river flows into lake Winnipeg in a deep channel, a hundred yards wide. The entrance is between sandy points, above which the channel opens into a shallow, weedy lake. It gradually narrows and becomes well defined at a little rapid, about 40 yards wide. Above this, it again expands to a width of from 60 to 100 yards, with even, clay banks from six to ten feet high, wooded with poplar. Low bosses of gray gneiss, with small groves of oak, outcrop here and there. The Indians rarely travel on the river as many portages are necessary.

Pigeon river has numerous concentrated falls or rapids; the descent in each, however, is not great. The greatest descent on the river is 29 feet at Shining fall. There are four rapids or falls with descents between 10 and 15 feet, fourteen with descents between 5 to 10 feet, and numerous others with descents of less than 5 feet. Many of the falls and rapids on this river can be combined to obtain workable heads. The discharge, metered by Mr. Leo G. Denis, at a point three-quarters of a mile below "First" rapid, was 2,629 second-feet on September 19, 1913. A record obtained by the Manitoba Hydrometric Survey on March 5, 1915, gave a flow of 1,164 second-feet.

The following are the principal rapids and falls in the order in which they are met in descending the river from Family lake:

Shining Fall is a gradual pitch, one-quarter mile long, flowing over hard bed rock, with a total descent of 29·0 feet. The river is divided into two channels; each of these is 100 feet wide with banks from five to ten feet high, following the general slope of the fall from head to foot.

Rapid, one-eighth mile below Shining fall, has a descent of two feet in 200 yards and could possibly be combined with the latter. The river is in two channels, each of which is 100 feet wide, with banks 20 feet high on the north side, and five feet or more on the south.

Balsam Rapid, nine miles below the last mentioned rapid, has a descent of 5·0 feet in a short chute falling over bed rock, above which is a swift 100 yards long. The river is 150 feet wide; the banks are

of hard rock, from ten to twenty feet high on the south side, but only five feet in height on the north. Above the rapid, the banks on both sides are only five feet high.

Rapid, one-quarter mile below Balsam rapid, can be combined with the latter. It has a descent of 5·2 feet in 70 yards. The river flows in three channels, 75, 30 and 20 feet wide, respectively, with banks varying from five feet in height at the head to 10 to 30 feet at the foot.

Rapid, one-quarter mile farther downstream, could be combined with the former two at slightly increased cost, as the banks are low. The descent is three feet in one hundred yards. The river is 50 feet wide, with rocky banks, 20 feet high. Below the rapid the banks are very low.

Little Goose Lake Rapid, one and a half miles below Little Goose lake, has a descent of four feet in one-quarter mile. At the head of this rapid the river is 150 feet wide, with rocky banks 15 feet in height; at the foot it is from 300 to 400 feet wide, with banks five feet high.

Rapid, one-half mile below Little Goose Lake rapid, has a descent of two feet in ten yards.

Grass Rapid, one and a half miles below the last mentioned rapid, has a descent of six feet in one-eighth of a mile. It consists of low chutes and rapids while the river is divided into several narrow channels with banks from 10 to 20 feet high. Below this rapid, the banks are only from four to five feet in height.

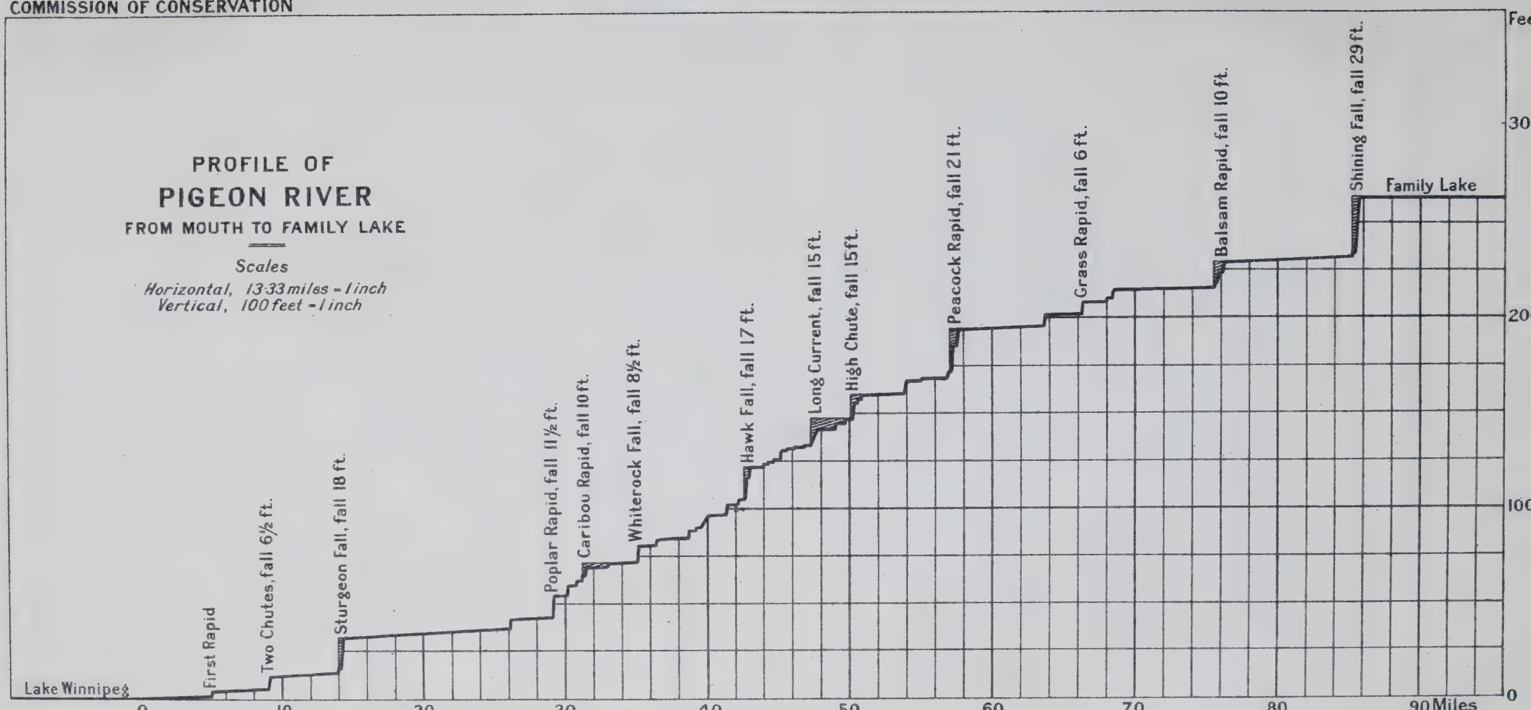
Rapid, two and a half miles below Grass rapid, has a descent of 5·9 feet in 40 yards. It occurs at a bend where the river is 50 feet wide, with rocky banks ten feet high at the head, and broadens to 100 feet, with banks 15 feet in height at the foot. Below the rapid the banks become very low.

Rapid, three miles farther downstream, has a descent of one-half foot in a distance of ten yards.

Peacock Rapid, three miles below the last mentioned rapid, has a descent of 7·6 feet in 100 yards. The river is 75 feet wide, and has rocky banks 20 feet high on the north and from 5 to 10 feet in height on the south side.

Lower Peacock Rapid, one-quarter mile below Peacock rapid, has a descent of 13·8 feet. The river at the head of this rapid is 150 feet wide, with rocky banks 20 feet high on the north side and gradually rising from 5 feet on the south; at the foot, it is from 400 to 500 feet wide, with banks 20 feet in height on both sides. This rapid and the Peacock could be combined in one development, giving a head of over 21 feet.

Rapid, three hundred yards below Lower Peacock rapid, has a descent of 3·3 feet in 30 yards. The river is 125 feet wide, with rocky


PROFILE OF
PIGEON RIVER
FROM MOUTH TO FAMILY LAKE
Scales
Horizontal, 13·33 miles = 1 inch
Vertical, 100 feet = 1 inch
Feet
300
200
100
0
Lake Winnipeg
0
10
20
30
40
50
60
70
80
90 Miles
First Rapid
Two Chutes, fall 6½ ft.
Sturgeon Fall, fall 18 ft.
Poplar Rapid, fall 11½ ft.
Caribou Rapid, fall 10 ft.
Whiterock Fall, fall 8½ ft.
Hawk Fall, fall 17 ft.
Long Current, fall 15 ft.
High Chute, fall 15 ft.
Peacock Rapid, fall 21 ft.
Grass Rapid, fall 6 ft.
Balsam Rapid, fall 10 ft.
Shining Fall, fall 29 ft.
Family Lake

banks from 10 to 15 feet high. Below this are small rapids and swifts with slight descents.

Sturgeon Skin Chute, has a descent of 6·9 feet in a distance of 70 yards, while the distance over the portage is only 30 yards. The river is 100 feet wide, with rocky banks 5 feet high at the head of the rapid and from 15 to 20 feet in height at the foot. Immediately below this rapid, the banks are of soil and are very low.

High Rapids, a series of rapids and swifts which begin three miles below Sturgeon Skin chute, extend for about three-quarters of a mile, with a total descent of six and one-half feet.

High Chute, one-eighth mile below the foot of High rapids, is a fall over a ledge, followed by a short stretch of rapids, with a total descent of 8·6 feet. The river is 300 feet wide, with two rocky islands near the middle. The banks are of rock from five to ten feet high. High chute and High rapids can be combined, giving a total head of over 15 feet.

Rapid, one-half mile below High chute, has a descent of two feet in 150 yards.

Rapid, five-eighths of a mile farther downstream, has a descent of three and one-half feet in 70 yards.

Long Current, one and a quarter miles below the last mentioned rapid, consists of rapids and a very swift current, occurring in a stretch of about 600 yards. The river, which is 70 feet wide, narrowing to 50 feet in places, has perpendicular rocky banks, 25 feet in height at the head and from 40 to 50 feet at the foot, giving a cañon-like appearance. This would afford a very good location for a dam, and a head of from 20 to 25 feet could be created. Below Long current is a stretch, one and a half miles long, where small rapids occur, with descents of from one-half to three-quarters of a foot.

Corner Chute, two and a half miles below Long current, has a descent of 4·3 feet in ten yards. Below this chute is a series of small rapids and swifts extending for a distance of over one mile, with descents of from one-half foot to two feet.

Hawk Chute, two and a half miles below Corner chute, has a descent of five feet in a distance of 30 yards. The river is 70 feet wide, with rocky banks five feet high.

Lower Hawk Chute, two hundred yards below Hawk chute, has a descent of 11·8 feet in 70 yards. The river is 300 feet wide, with rocky banks, 20 feet high on the north, and from 5 to 10 feet high on the south side. The Hawk and Lower Hawk chutes could be combined to give a total head of about 17 feet.

Rapid, one-half mile below Lower Hawk chute, has a descent of two and one-half feet in 100 yards. The river is 70 feet wide; the

rocky banks, almost perpendicular, are 50 feet in height on the south and 25 feet on the north side.

Rapid, three-quarters of a mile farther downstream, has a descent of 5·1 feet in 125 yards. The river is 70 feet wide, and has rocky banks, 20 feet high on the south side and 15 feet on the north.

Adjoining Rapids are one and a quarter miles below the preceding rapid. They consist of a series of rapids occurring in close succession and covering a distance of about one-half mile. The distance across the portage road, from head to foot, is only 250 yards. The total descent is 7·4 feet. At the head, the river flows in two channels; each is 100 feet wide, with rocky banks, 10 feet high on the south side and 20 feet on the north. Just above the head of these rapids, the banks are very low, about five feet in height, and composed of clay.

Round Lake Rapid, one mile below Adjoining rapids, has a descent of 4·5 feet in a distance of 75 yards. Below Round lake are small rapids and swifts covering a distance of one and one-half miles.

White Rock Chute, three miles below Round Lake rapids, has a descent of 8·3 feet. An island divides the river here. The rapid consists of two chutes with 100 yards of rough waters intervening. The south channel is 125 feet wide, with rocky banks, 15 feet high on the north side, and from 5 to 10 feet in height on the south. Below this there are swift waters, and a small rapid, extending over a distance of two miles.

Narrow Rock Rapid, four miles below White Rock chute, has a descent of 1·8 feet in 20 yards, and is followed by three-quarters of a mile of very swift water. The river flows in two channels, 70 and 40 feet wide respectively, with rocky banks, 20 feet high. The island is only five feet in height.

Caribou Rapid, one and a half miles below Narrow Rock rapid, has a descent of 4·4 feet in 125 yards. The river is 40 feet wide, with banks from 20 to 30 feet high; but, just above this rapid, the banks are of clay and only 5 feet in height on the north side.

Lower Caribou Rapid, one-quarter of a mile below Caribou rapid, has a descent of two and one-half feet in 100 yards. The river is 70 feet wide and has rocky banks ten feet high. Narrow Rock, Caribou and Lower Caribou rapids can be combined to give a total head of about 10 feet.

Rapid, three and a half miles below Lower Caribou rapid, has a descent of 1·8 feet in 75 yards.

Slide Rapid, three-quarters of a mile farther downstream, has a descent of 5·5 feet in 20 yards. The river flows in two channels at high

water; these are 100 feet and 50 feet wide, respectively. The banks are of clay and rock, five feet high.

Poplar Rapid, one mile below Slide rapid, has a descent of 11·3 feet in 120 yards. The river is 150 feet wide; the banks are of rock and clay, 15 feet high on the south and eight feet high on the north side.

Lynx Rapid, three miles below Poplar rapid, has a descent of 4·8 feet in 150 yards. At high water the river flows in two channels; 120 feet and 40 feet wide, respectively, at the head, and with rocky banks 30 feet high. The river broadens at the foot of the rapid.

Sturgeon Fall, twelve miles below Lynx rapid, has a descent of 15·4 feet in 150 yards. The river is divided into two channels by a large island; the north channel, along which the levels were taken, is 70 feet wide, with rocky banks 5 feet high at the head, and 15 feet in height near the foot of the fall. Below this fall, for a distance of more than six miles, the river has low, marshy banks.

Rapid, two hundred yards below Sturgeon fall, has a descent of 2·2 feet in 15 yards and can be combined with Sturgeon fall to give a total head of nearly 18 feet.

The Two Chutes, five miles farther downstream, have a descent of 6·6 feet in 50 yards. The river is 400 feet wide, with banks of clay and rock, five feet high. At one point on the north side, the bank rises to 15 feet.

First Rapid, four miles below The Two chutes, has a descent of 3·1 feet within 100 yards.

Berens River

The mouth of Berens river is nearly halfway up lake Winnipeg, on its eastern side. The country adjoining the river as far as the first rapid, 11 miles upstream, consists of many low, hummocky, gneiss hills, which, seldom rising 20 feet above the water, are partly covered with a heavy, clay soil; along the river banks the soil is deeper.

As far as the first portage, the river flows between rocky banks from 10 to 20 feet high, alternating with low, swampy ground. The current is sluggish, while the water is deep and of a dark brown colour, although comparatively free from floating matter.

The Berens river has numerous concentrated falls or rapids, but the descent in each is not very great. The greatest is at Nightowl rapid, which has a descent of 39 feet. Little Grand rapid has a descent of 21·2 feet. There are six rapids with descents of between 10 and 15 feet, ten with descents of between 5 and 10 feet and numerous others with descents of less than 5 feet. Many of these could be combined to obtain a head of water which it would be pro-

fitable to develop. Between the chutes there is little or no current. The discharge of the Berens, metered by Mr. Leo G. Denis at a point two miles above "First" rapid, was 1,744 second-feet on September 10, 1913. The discharge of the Etomami, a small river paralleling the Berens and emptying into it, was 234 second-feet at a point just above its mouth, on September 9, 1913. A record obtained by the Manitoba Hydrometric Survey on March 2, 1915, gave a discharge of 634 second-feet for Berens river.

Family lake, which is an expansion of the Berens river, also forms the headwaters of the Pigeon river described above; the two streams, after following irregularly parallel courses, enter lake Winnipeg only six miles apart.

The following are the principal falls and rapids on the Berens river, mentioned in the order in which they are met in ascending the river from its mouth:

First Rapid, eleven miles above the mouth, has a descent of 11·4 feet in 100 yards. The river flows in two narrow channels, from 25 to 40 feet wide, with rocky banks.

Chute, four hundred yards above First rapid, has a descent of 3·7 feet in 20 yards. This can be combined with First rapid, giving a total head of over 15 feet.

Grass Rapid, four and one-half miles above the preceding chute, has a descent of 4·1 feet in 50 yards. The river is 200 feet wide, and contains numerous small, rocky islands. The banks at the head of the rapid are from 10 to 15 feet in height.

Wolverine Rapid, one-half mile above Grass rapid, has a descent of two feet.

Flatrock Rapid, one-half mile above Wolverine rapid, has a descent of 3·5 feet. It occurs at a bend in the river and the distance across the portage road is 80 yards.

Rapid, one-half mile above Flatrock rapid, has a descent of two feet.

Island Rapid, two hundred yards farther upstream, has a descent of 10 feet within 60 yards.

The descents between Wolverine and Island rapids, inclusive, can be combined, as the banks along these rapids remain quite high. The total head, thus rendered available, would be over 17 feet.

Kettle Rapid, three-quarters of a mile above Island rapid, has a descent of two feet in 50 yards.

Netmending Rapid, three miles above Kettle rapid, has a descent of 2·9 feet in 30 yards.

Roundtent Chute, one and a half miles above Netmending rapid, has a descent of 5·1 feet and consists of a perpendicular chute falling

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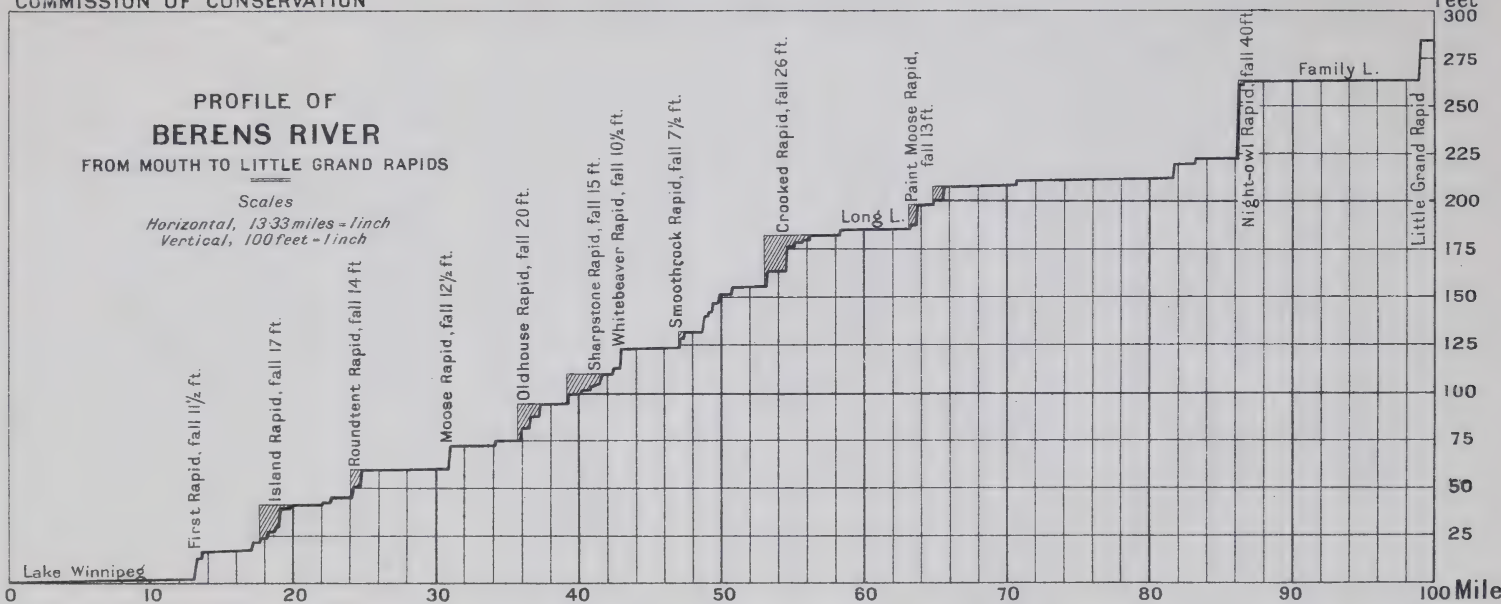

over a ledge of rock. The river is 50 yards wide and has rocky banks from 10 to 15 feet high.

Upper Roundtent Rapid, one-half mile above Roundtent chute, has a descent of 8·9 feet in 100 yards. The river, which is here 50 feet wide, has rocky banks from seven to 15 feet in height.

The banks between the two Roundtent rapids are low in only a few places and the descents in these two rapids could possibly be combined, giving a total head of 14 feet.

Moose Portage Chute, six miles above Upper Roundtent rapid, consists of a series of chutes over rock in a narrow channel of the river. At the foot, the river is only 50 feet wide and flows between perpendicular, rocky banks from 15 to 25 feet high, thus affording a very good site for a dam. The descent is 12·5 feet within a distance of 300 yards, as measured along the portage road.

Rapid, three miles above Moose Portage chute, has a descent of two feet in 50 yards.

Lower Oldhouse Rapid, one and three-quarter miles farther upstream, has a descent of 6·3 feet within 100 yards.

Flag Rapid, one-half mile above Lower Oldhouse rapid, has a descent of 6·3 feet in a distance of 25 yards. The river is 30 feet wide and the rocky banks are from five to ten feet high.

Upper Oldhouse Rapid, three-eighths of a mile above Flag rapid, has a descent of 6·4 feet; it consists of a chute with a rapid below, which is 50 yards in length. The river is 150 feet wide, with a large, rocky island in the centre, and the rocky banks are from 10 to 20 feet high. The last three rapids can be combined to give a total head of nearly 20 feet.

Stick Chute, two miles above Upper Oldhouse rapid, consists of a perpendicular chute falling over a ledge of rock, with a descent of 4·7 feet. The river is 250 feet wide, with rocky banks from 10 to 20 feet high.

Water Rapid, three-quarters of a mile above Stick chute, has a descent of two feet in a chute over a ledge.

Road Portage Rapid, three-quarters of a mile above Water rapid, has a descent of 2·1 feet and comprises a series of low chutes over ledges, extending over a distance of 200 yards along the river.

Sharpstone Chute, one-half mile above Road Portage rapid, has a descent of 5·9 feet in a distance of 25 yards. The river, which is 125 feet wide, is narrowed by a projection jutting out from the south shore; at high water, this becomes an island with a very narrow channel on the south side. The banks of rock are 15 feet or more in height.

The different descents, between Stick chute and Sharpstone chute, inclusive, could be combined, as the rocky banks along the river

between these two points maintain a height of from 15 to 20 feet. The total head thus obtained would be over 16 feet.

Island Rapid, three-quarters of a mile above Sharpstone chute, has a descent of 2·2 feet in a distance of ten yards. The river has two narrow channels with high, rocky banks.

Whitebeaver Rapid, one-half mile above Island rapid, has a descent of 10·5 feet within 150 yards. The river flows in several narrow channels separated by large, rocky islands. The broadest channel is only 30 feet wide at the head and 50 feet at the foot of the rapid. The rocky banks are ten feet or more in height.

Smoothrock Rapid, four miles above Whitebeaver rapid, has a descent of 4·7 feet in a distance of 30 yards.

Rapid, one-quarter mile above Smoothrock rapid, has a descent of 2·8 feet within ten yards. It could be combined with Smoothrock rapid, thus giving a total head of 7·5 feet.

Sandisland Chute, one and one-quarter miles farther upstream, has a descent of 9 feet in a distance of 70 yards.

Rapid, one-quarter mile above Sandisland chute, has a descent of 2 feet in a distance of 15 yards.

Liver Rapid, one-quarter mile above the last mentioned rapid, has a descent of 4·7 feet in a distance of 30 yards. The descent from Sandisland chute to Liver rapid, inclusive, could be combined to give a total head of more than 15 feet.

Shortcut Chute, one-half mile above Liver rapid, has a descent of 4 feet within 60 yards. The river has two channels, 70 feet and 125 feet wide, respectively, with low banks consisting of soil over rock.

Shoreroad rapid, three-quarters of a mile above Shortcut chute, has a descent of 3·7 feet in 300 yards. The river, at this point, is narrow and has rocky banks 20 feet in height.

Child Portage Rapid, two and a half miles above Shoreroad rapid, has a descent of 7·9 feet. The river here is divided into several channels and has rocky banks 20 feet high. The distance, as measured along the portage road, is only 150 yards, but is much longer following any of the river channels.

Rapid, one and a half miles above Child Portage rapid, has a descent of 1·7 feet in a distance of 50 yards.

Crooked Rapid, one-eighth of a mile farther upstream, has a descent of 11·2 feet in 100 yards. The river flows in several narrow channels, and the rocky banks are 15 feet or more in height.

Wolf Chute, one-half mile above Crooked rapid, has a descent of 3·1 feet in ten yards. The river is 50 yards wide, with rocky banks which are from 10 to 15 feet high.

Etomami Chute, one mile above Wolf chute, has a descent of 1·8

feet in 25 yards. The river is 70 feet wide, having rocky banks, five feet or more in height. The descents between Child Portage rapid and Etomami chute, inclusive, could be combined, giving a total head of more than 26 feet.

Long Lake Chute, two miles above Etomami chute, has a descent of 3 feet. The river is divided into several channels by large, rocky islands, with a short chute in each channel. The banks are 10 feet or more in height.

Rapid, near the head of Long lake, five miles above the last-mentioned chute, has a descent of 2·3 feet in a distance of ten yards.

Painted Moose Chute, one-half mile farther upstream, has a descent of 10·8 feet within 100 yards. The river flows in two channels; each of these is 20 feet wide, with rocky banks 25 feet high. The rapid near the head of Long lake could be combined with this, giving a total head of more than 13 feet.

One mile above Painted Moose chute, the river divides into two channels, one of which is much smaller than the other. The smaller channel could be used as a headrace, as there are two sharp descents, one-half mile apart, before it joins the main stream. The total head at this point would be 8·4 feet.

Manitou Rapid, five miles above the foot of the small channel above described, has a descent of 2 feet in 20 yards.

Crane Rapid, eight miles above Manitou rapid, has a descent of 7·6 feet in 100 yards. The river is divided into two channels, 50 feet and 20 feet wide, respectively. The banks are from 5 to 10 feet high at the head, and 20 feet in height at the foot of the rapid.

Whiteman Rapid, one and a half miles above Crane rapid, has a descent of 2·4 feet in ten yards. The river flows in two or three channels, according to the stage of the water, with banks 5 to 10 feet high.

Nightowl Rapid, three miles above Whiteman rapid, has a descent of 39 feet; the distance over the portage road is 420 yards. The river is divided into several channels by rocky islands; the total width at the foot is, approximately, 1,000 feet, of which only about half is water. The banks are from 10 to 15 feet high, following the general slope of the rapid.

Rapid, one-quarter of a mile above Nightowl rapid, has a descent of 1·4 feet in a distance of 50 yards. This rapid could be combined with Nightowl rapid, giving a total head of more than 40 feet.

Little Grand Rapid, three-quarters of a mile above Family lake, has a descent of 21·2 feet in 400 yards. The river is divided into three channels, approximately 300, 200 and 50 feet in width, respectively. The rocky banks are ten feet high and follow the general slope of the rapid. Below the main rapid is a stretch of rough water which would add one or two feet to the head.

DISCHARGE MEASUREMENTS OF BERENS RIVER

Below First Fall.		Above Little Grand Rapid.	
Date	Discharge Sec.-ft.	Date	Discharge Sec.-ft.
1914		1914	
February 28	530	July 1	7,001
June 13	1,126	July 9	7,262
July 27	2,190	August 28	3,168
September 8	1,160		

Poplar River

The Poplar river flows into an inlet on the east shore of lake Winnipeg, about midway between the north and south extremities of the upper main body of the lake.

The general direction of the river from its source to lake Winnipeg is north-westerly. It drains 1,950 square miles, approximately.

The lower portion of the basin is confined between the Big Black river and the Leaf river systems, but above this the drainage widens out. Large areas of this upper watershed are stated to be low and swampy, with rocky ridges at various points. Practically all drainage from the headwaters passes through Thunder lake, situated some 25 miles above the mouth of the river.

The Poplar is only navigable by canoe, and, as no railway traverses this territory, the only means of access is by lake Winnipeg steamers.

An Indian reserve, situated at the mouth of the river, is the only settlement in the immediate vicinity.

Numerous Water-powers

The power possibilities of this river have not been fully investigated, but it is stated that several rapids occur, the more important being in the reach of the river below Thunder lake.* An estimate of the mean annual discharge of the river, based on a run-off of 0.3 second-feet per square mile, would give a discharge of 585 second-feet.

*Note by L. G. D.—The following rapids are reported between the confluence of the North branch and the mouth:

Rapid, four miles above Thunder lake, has a descent of 20 feet in 100 yards.

Rapid, two miles farther down stream, has a descent of 16 feet in 630 yards.

Rapid, four and a half miles below Thunder lake, has a descent of nine feet in 25 yards.

Rapid, one mile below the preceding rapid, has a descent of four feet in ten yards.

Rapid, two and a quarter miles farther down, has a descent of nine feet in 100 yards.

Rapid, one-half mile below, has a descent of four feet in 120 yards.

Whitemud rapid, eight and a half miles farther down stream, or 16¾ miles below Thunder lake, has a descent of nine feet in 200 yards.

Balsam rapid, six and a half miles below Whitemud rapid, has a descent of 12 feet in 150 yards.

"First" rapid, five miles below Balsam rapid, has a descent of 10 feet in 200 yards.

Pigeon River—Peacock Rapid

Berens River—Sandisland Chute

Big Black River

The Big Black river discharges into an inlet on the east shore of lake Winnipeg, about 40 miles from the northerly extremity of the lake.

Situated, as Big Black river is, in a portion of Manitoba which is unsurveyed and difficult of access, little is known as to the extent of the descent occurring on this river, but it is known that there are rapids at several points.*

The general direction of the river from its source is about west-northwest. The drainage area is estimated to comprise 1,350 square miles, but little is known concerning the upper portion of the basin. About 40 miles above the mouth, the Pelican river is tributary to the Big Black, and between this point and lake Winnipeg the over-

*Note by L. G. D.—It is reported that the course of this river is broken by some thirty-three rapids; the more important are the following:

Rapid, five miles above the mouth, has a descent of 13 feet in 75 yards.

Cathead rapid, 13 miles above the mouth, has a descent of 7 feet in 130 yards.

High rapid, 17 miles from the mouth, has a descent of 25 feet in 100 yards.

Island rapid, two and one-half miles above High rapid, has a descent of 15 feet in 150 yards.

Mink rapid, 23½ miles above the mouth of the river, has a descent of 5 feet in 300 yards.

Rapid, two and a quarter miles above Mink rapid, has a descent of 7 feet in 220 yards.

Long rapid, two and one-half miles farther up, has a descent of 57 feet in one and one-half miles.

Rapid, three and one-half miles above Long rapid, has a descent of 8 feet in ten yards.

Pelican rapid, five miles above Long rapid, or 36¾ miles from the mouth, has a descent of 6 feet in 50 yards.

Rapid, one and one-half miles above Pelican rapid, has a descent of 4 feet in 20 yards.

Rapid, two and three-quarter miles above Pelican rapid, has a descent of 9 feet in 100 yards.

Skunkfeet rapid, eight miles farther up, has a descent of 12 feet in 200 yards.

Rapid, one mile above Skunkfeet rapid, has a descent of 5 feet in 40 yards.

Rapid, one and one-half miles farther up, has a descent of 7 feet in 90 yards.

Rapid, six miles above Skunkfeet rapid, has a descent of 5 feet in 75 yards.

Rapid, one and one-half miles above the latter, has a descent of 5 feet in 50 yards.

Adjoining rapid, one mile farther up the river, and 56 miles from the mouth, has a descent of 20 feet in one mile.

Rapid, three miles above Adjoining rapid, has a descent of 10 feet in 100 yards.

Rapid, thirteen miles farther upstream, has a descent of 6 feet in 40 yards.

Rapid, one mile above the latter, has a descent of 5 feet in 10 yards.

Rapid, two miles farther up and 19 miles above Adjoining rapid, has a descent of 13 feet in 45 yards.

lying soil is clay, with rock outcrops. In the upper reaches, the land is reported to be low and swampy, and the banks marshy, with fringes of reeds and rushes extending into the river. In the lower reaches, comprising the clay belt, a mixed growth of pine, spruce, balsam and poplar is reported, but the growth in the upper watershed is principally of willows.

The river is navigable only by canoe, and the means of access is by boat from Selkirk during the period of navigation. There are no settlements in the vicinity of the river, but it is stated that trappers frequent the region in winter.

Assuming a drainage of 1,350 square miles, and mean annual run-off of 0.3 second-feet per square mile, the mean annual discharge at the mouth is estimated at 400 cubic feet per second.

Bélanger River

The Bélanger river discharges into lake Winnipeg, on its eastern shore, about 20 miles from the north end of the lake. It rises in the vicinity of Gunisao lake and flows in a westerly direction to lake Winnipeg.

Its basin is narrow, varying from 10 to 15 miles in width, and lies between the Gunisao river to the north and the Big Black river to the south. The country for the greater part is level, with the exception of a few rocky hills.

General Description of River

For the first nine miles above the mouth the banks are stated to be from 6 to 15 feet in height, and are composed of clay, with very few rock outcrops. Outcrops do occur, however, at all rapids throughout the extent of the river. The banks above the first rapids gradually increase in height to some 18 feet, being still composed of clay. In the upper reach of the river, rock outcrops and overlying soil of clay are encountered, both at rapids and along the quieter stretch of the river.

The first nine miles of river varies in width from 200 to 300 feet; above this the stream narrows, and, in the upper waters, the bed is strewn with boulders.

It is reported that much of the tributary territory has been burnt over, with the destruction of considerable timber, but there is still a growth of poplar and black spruce near the river.

Owing to several rapids on the river, navigation is only possible by either rowboat or canoe. During the navigation season, the mouth of the river is accessible by steamer from Selkirk.

Though the upper portions of the watershed have not been explored, it is estimated that the Bélanger river has a drainage area

of 730 square miles. Assuming that the mean annual run-off is 0.3 cubic feet per second per square mile, the mean annual discharge would be 225 cubic feet per second at the outlet. In the absence of discharge measurements, no estimate is made respecting the maximum or minimum flow, and even the mean stated above is subject to revision when such data are obtained.

Power Possibilities not as yet known

Investigations of the power possibilities of this river have not been made, but it is known that considerable descent occurs, and that it is concentrated at several points, indicating power possibilities. At the first rapids above the mouth, a fall of about eight feet is reported, while above this there are many rapids which are impossible to navigate and necessitate portages.*

Additional Rivers in Lake Winnipeg Basin

In the lake Winnipeg basin there are also the following rivers:—

ETOMAMI RIVER practically parallels Berens river, flowing into the latter a few miles above lake Winnipeg. The total estimated fall in the river is 180 feet; two of the rapids have descents of 8 feet and 15 feet respectively. For the discharge of this river see under Berens river p. 91.

GUNISAO RIVER has two important rapids below its forks; the North branch has 10 portages, while there are 22 on the South branch.

FISHER RIVER flows into lake Winnipeg from the west; the total fall from the forks to the mouth is 20 feet. The river is broken by three rapids in this stretch.

* Note by L.G.D.—There are reported to be 21 portages on this river.

CHAPTER V

Nelson River and Tributaries and Hayes River*

The Nelson river flows through the central portion of northern Manitoba. Rising in the northerly end of lake Winnipeg, it flows in a general north-easterly direction, discharging into the southwest corner of Hudson bay.

The Nelson river, as the outlet of lake Winnipeg, discharges the waters collected from an immense drainage area. It is one of the main drainage systems of the northern continent, having a tributary area of approximately 450,000 square miles. This vast area extends from the height-of-land, a short distance west of lake Superior, to the Rocky mountains. To the north, the basin is bounded by the Athabaska and Churchill watersheds, while the southern drainage extends down into the Northern States. Rivers tributary to lake Winnipeg, and having immense areas of tributary drainage themselves, comprise such systems as those of the Winnipeg, Red, Dauphin and Saskatchewan rivers. Numerous smaller rivers, including the Berens, Pigeon, Manigotagan and Brokenhead, also contribute to the flow from lake Winnipeg.

Exceptional Physical Characteristics

Practically a complete range of physical characteristics or conditions is found throughout the basin, comprising, as it does, the drainage from the eastern slopes of the Rocky mountains, extending thence to the prairie section of Western Canada, and again farther eastward to the rocky and hummocky country of the Laurentian plateau. Similarly, there is a wide diversity of vegetation and forest growth within the basin.

The drainage directly tributary to the Nelson is small in extent as compared to that tributary to lake Winnipeg, but it includes the following rivers: Burntwood, Limestone, Kettle and several smaller streams.

From the tremendous expanse of lake Winnipeg and its tributary systems of great lakes, comprising lakes Manitoba and Winni-

* In this chapter, a portion of the description of the Nelson river was contributed by the Water Power branch of the Department of the Interior.

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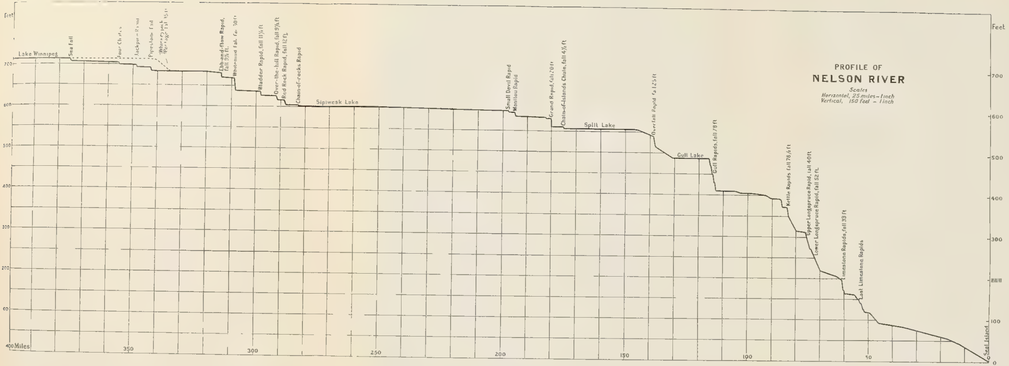


pegosis, a natural regulation of the flow of the Nelson river results, and the range between flood and minimum discharge is not high. In this respect, it is similar to the St. Lawrence, which is regulated by the Great lakes.

General Description of River

The length of the river from lake Winnipeg to Hudson bay, as determined by a survey made by Dr. Otto J. Klotz, is 430 miles. In this distance a descent of 713 feet occurs. The upper reaches of the river are more properly described as a chain of lakes connected by falls or by reaches of river and rapids. In this upper portion of the river, extending approximately to Split lake, some 250 miles from lake Winnipeg, the banks are in general higher than in the lower portion. Although the river, as stated, expands in this upper section into many lakes of slow-running water, yet the falls are more sharply defined and are usually of steeper descent than those in the lower reaches, and also are often separated by islands into numerous narrow channels. Not only are the banks lower as lake Winnipeg is approached, but the distance between them increases. The descent in the lower portion is less abrupt, being more often a series of rapids or swift-running water. These latter characteristics gradually become more accentuated as Hudson bay is approached.

Broken by many Rapids

Expanding into Playgreen lake, a short distance below lake Winnipeg, the river flows from the former lake through two main branches, separated by Ross island, and known as the East and West rivers. The East river, on which occurs Sea River fall, is narrowed at many points by islands, although, later, it expands into Pipestone lake. The West river is wider, and is navigable by steamboat to Whisky Jack portage, which is near the junction of the two branches at Cross lake. From this lake to Sipiwesk lake, the river at first flows between islands, and descends through the Ebb-and-flow rapids, followed by the Whitemud fall. The Bladder rapid follows, in which the river flows in one narrow channel. Below this rapid, it again divides into two main channels before Sipiwesk lake is reached. On the eastern channel three rapids occur, Over-the-hill, Red Rock and Chain-of-rocks rapids. Below Sipiwesk lake, to the Manitou or Devil rapid, the river is more contracted and retains this feature until it reaches Split lake. In the reaches above Split lake is Grand rapid, followed very closely by the Chain-of-islands rapid. Birthday, or Overfall, rapid follows in the stretch of river to Gull lake. Below this latter lake, the river expands, and is divided by islands, with the formation of Gull, Kettle and

Long-spruce rapids. From Long-spruce rapid to Hudson bay, in which stretch the Limestone rapid occurs, the river is generally wider and freer of islands.

Nature of River Banks

Throughout its course, rock outcrops occur at practically all rapids. The soil overlying the rock is principally clay, with some deposits of gravel and boulders. The banks, where rapids are situated, range in height from 10 to 70 feet in the upper portion of the river.

A scattered growth of timber, including spruce, birch and poplar, occurs along the river. The clay soil overlying the rock formation is stated to be very fertile, and root crops are grown at Norway House, Cross Lake and Split Lake. Wheat is also said to have been grown at the two former places.

High water takes place during midsummer, while the period of low water is usually the late winter months. It is also stated that the extreme range between these two periods is never more than six feet.

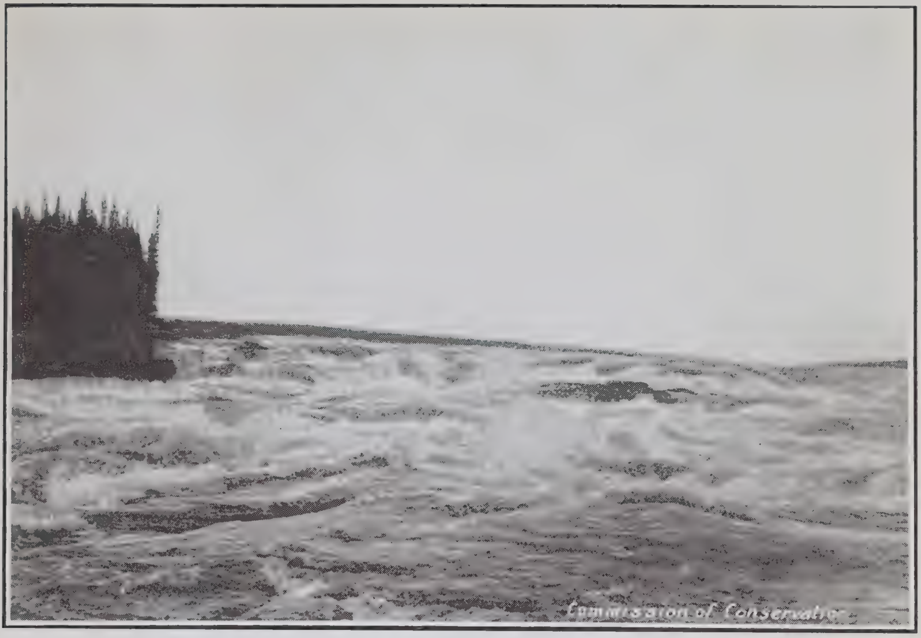
Steamboats navigate the Nelson from lake Winnipeg to Whisky Jack portage, but, below this point, navigation is only possible in certain portions of the river. It will be crossed at two points by the Hudson Bay railway.

Surveys of the River

In 1878 Dr. Robert Bell made a geological examination of the river from lake Winnipeg to the mouth. A similar survey was made in 1902 by Mr. J. B. Tyrrell, also of the Geological Survey. A reconnaissance survey in the interests of navigation, was made by the Department of Public Works of Canada in the autumn of 1909. Surveys carried on by the Water Power branch of the Department of the Interior include a reconnaissance of the power possibilities of the upper portion of the river, by the late William Ogilvie, in 1910, and also discharge measurements of the East and West rivers during the season of 1913.

Run-off Records not Complete

Precipitation.—As no precipitation records are available for the greater portion of the drainage area, it is impossible to estimate the mean for the whole area. The following table gives the mean annual precipitation for certain stations lying within the basin. It will be noted that there is a wide range in the precipitation:—



Nelson River—Grand Rapid (at Head)

Nelson River—Whitemud Fall (West Channel)

Station	Period of record		Term, in years	Precipitation, in inches
	From	To		
Winnipeg, Man	1873	1912	40	21.6
Kenora, Ont.	1886	1912	9	22.4
Channel island (lake Winnipeg)..	1890	1903	13	17.1
Norway House, Man.	1896	1904	8	18.9
Moorhead, Minn.	1881	1908	28	24.9
Prince Albert, Sask.	1903	1912	9	17.1
Edmonton, Alberta	1883	1912	28	16.4
Calgary, Alberta	1886	1909	23	18.6
Macleod, Alberta	1896	1912	15	13.6
Banff, Alberta	1891	1912	19	20.3

Discharge Measurements.—Several discharge measurements have been made on the Nelson river, though none of them, apparently, determine its low-water flow. Discharge measurements made by Mr. William Ogilvie in the latter part of August, 1910, in the vicinity of Whitemud fall, indicate a discharge of 109,364 second-feet. Mr. Miles, of the Department of Public Works, obtained a discharge measurement at the outlet of Sipiwesk lake on October 6, 1909, at what was stated to be a very low stage of the river; this recorded a flow of 118,369 second-feet. In September, 1913, measurements of the flow of the East and West rivers were made by Alexander Pirie, of the Manitoba Hydrometric Survey. On September 16, 1913, the total flow of the East river, below Sea River fall, was 19,762 second-feet. On September 25, 1913, the flow on the West river, in the vicinity of Whisky Jack portage, was 46,549 second-feet. At the time of metering the West river, a storm from the northwest lowered the level of lake Winnipeg at its outlet, which undoubtedly greatly decreased the flow.

A regular metering station was established by the Manitoba Hydrometric Survey at the Manitou rapid on July 18, 1914, and continuous readings secured till September 24 of the same year; the discharge during this period ranged from 87,000 to 103,000 second-feet. Records were also secured at this station during the winter of 1914-15, a low flow of approximately 45,000 second-feet being recorded.

Storage Possibilities

As stated previously, any extreme variation in the flow of the Nelson river is hardly possible, due to the immense expanse of lake Winnipeg, which offers unexcelled facilities for storage regulating the flow. The lake comprises an area of 9,414 square miles, and, in extent, ranks fifth in superficial area of the lakes of North America; it is over 2,000 square miles larger than lake Ontario and slightly smaller than lake Erie.

The following table gives an estimate of the flow which a storage of only two feet would render available for periods of either three months, six months or a year:

Depth of storage	Storage in billions of cubic feet	Rate of draught in second-feet		
		Period, 3 mos.	Period, 6 mos.	Period, 1 year
1 foot	262.30	33,260	16,630	8,315
2 feet	524.60	66,520	33,260	16,630

Power Possibilities

In considering the character of its rapids and falls, the Nelson may be divided into three sections: (1) from the mouth to Kettle rapids; (2) from Kettle rapids to Split lake; (3) above Split lake.

In the lower portion, namely, below Kettle rapids, it is generally very wide and free from islands where rapids occur. The rapids have a very gradual descent, are quite long, and, on account of the great width of the river, the prospects for power development are not very attractive.

In the portion between Split lake and the foot of Kettle rapid, there are many islands where the rapids occur. The rapids are steeper and, although, in some cases, the banks are rather low, this portion offers greater possibilities than the lower.

In the two sections just described, which include all the river below Split lake, there is a practically continuous series of rapids and swifts. Even between rapids there are no still-waters; these stretches are either swift or rough.

Above Split lake, the rapids and falls are well-defined, and their descents are generally steep as compared with those in the lower portion of the river. In this section, except above Pipestone lake, the stretches between the chutes or rapids have very sluggish currents; the total descent in the river really occurs only at the chutes and rapids which, especially above Sipiwesk lake, occur in numerous narrow channels separated by islands. Where these islands are situated, the river is quite wide, but the individual channels between islands are narrow. Power development in this part of the river should be accomplished easily; respecting the higher falls, *i.e.,* those over eight or ten feet in height, there is no doubt that the total head can be utilized, while the chutes and rapids with less descent might be combined or used to increase the natural heads of the higher falls.

General Description

In ascending the Nelson river from its mouth, Seal island is the first landmark passed; from this island upward, the current is quite swift. The river is about three-quarters of a mile wide, with clay banks from 50 to 100

feet high. At a large island, 15 miles farther upstream, the river narrows somewhat and its depth increases as the current slackens slightly. The banks here are lower and less steep and, at a point 32 miles above Seal island, opposite a group of three islands, they become very low on the west side. Commencing eight miles above the last mentioned group, the river widens again, the current becomes much more sluggish and the banks are alternately low and high, varying from eight to fifty feet. Limestone begins to appear at low points in the river seven miles farther up and rough water may also be noticed near the shores; high clay banks are still a feature.

Rapids below Last Limestone Rapids.—These are, in reality, merely rough water and swifts which extend over a distance of four miles, with a descent of from five to ten feet per mile. The width of the river is one-half mile. The banks, which are of clay, over limestone, vary from 20 feet to 100 feet in height; at one place, on the west side, they are only two or three feet above water but gradually rise to 30 feet. As heads would have to be created by dams power development here, while not impossible, would be almost prohibitive on account of the cost under present conditions. Above the rapids, three or four miles of smoother, but still moderately swift, water are encountered before reaching Last Limestone rapids.

Last Limestone Rapids

These rapids may be divided into four different pitches, as follows:

First Pitch, three-quarters of a mile long, with a descent of six feet. The river is three-quarters of a mile wide; the banks, on the west side, are 80 feet in height and consist of clay over limestone; on the east side they are composed of limestone but rise to a height of only 20 or 30 feet.

Second Pitch, one mile long, with a descent of 15 feet, ten feet of which occurs within three-eighths of a mile. The river is one-half mile wide, with banks similar to those in the first pitch.

Third Pitch, three-quarters of a mile long, with a descent of ten feet. The width of the river is five-eighths of a mile and the banks here also are similar to those in the first pitch.

Fourth Pitch, one and one-half miles long, has a descent of ten feet. The river is three-quarters of a mile wide, and the banks are similar in composition to those in the first pitch but rise to a height of 40 feet on the east side.

Again, in the case of these four pitches, the whole head would have to be created by a dam or dams, and the cost of development would be very high. Between Last Limestone and Limestone rapids, there are five miles of fairly smooth water. The foot of the latter rapids is immediately below the mouth of Limestone river.

Limestone Rapids

These rapids may be divided into two portions, of which the upper is much the more important.

Lower Pitch is one-eighth mile long, with a descent of eight feet. The river is one mile wide; the banks are of clay, over limestone, and are from 50 to 75 feet in height. This part of the rapid is immediately below the bend where Limestone river enters; on the west side it makes a sheer drop of four feet, while on the east side the descent is more gradual.

Upper Pitch is the first attractive site on the river from a power-development standpoint. The portage is three-quarters of a mile long; the distance is nearly as great along the river and the descent is 25 feet. The stream is three-quarters of a mile wide, with banks of clay and limestone, from 50 to 75 feet high. The rapid on the west side is very rough and quite steep. Possibly a wing and longitudinal dam development would utilize a great portion of the flow.

Above the Limestone rapid is a stretch of water two miles long, having a uniform descent of from five to eight feet per mile. Above this are eight or nine miles of fairly smooth water before the foot of the Lower Long-spruce rapid is reached.

Long-spruce Rapids

Lower Long-spruce Rapid.—This rapid is four miles in length, and has a descent of 52 feet. It consists of a series of low cascades over granite ledges, with the rock visible in most parts of the river. The river is very wide in this portion but narrows to one-half mile at the foot of the rapid. The banks are of clay rising to a height of 70 feet; at a few points, they are as low as ten feet near the river, but gradually slope upward from the shore.

Upper Long-spruce Rapid.—This rapid is two miles long and has a descent of 40 feet. It comprises a series of cascades and rapids passing over granite, which shows throughout the breadth of the river. In the lower portion, the pitches are quite appreciable and continuous; the high clay banks, however, have disappeared and the river is less than one-half mile wide. One of the stretches which is portaged showed a descent of 25 feet in less than three-quarters of a mile. Then follow four miles of smooth water before the foot of Kettle rapid is reached.

Kettle Rapid

This rapid may be divided into three pitches, as follows:

First Pitch is three miles long, and has a descent of approximately forty feet. The river is from five-eighths to three-quarters of a mile wide, with banks of clay or red granite, from 20 feet to 50 feet high; these become lower farther up the river and, in the upper portion, are only 15 feet high. In the lower portion of this pitch, rocks show

throughout the width of the river; these give place to islands as the higher section is reached. The descent in this portion of Kettle rapid could possibly be utilized by creating heads at two different points.

Second Pitch affords great facility for power development on account of the narrowness of the river near the foot of the rapid. At this point the river, which is only about 200 yards wide, is to be crossed by the Hudson Bay railway. This narrow width prevails only for a distance of 300 yards near the foot of this pitch, above which the stream broadens again to a width of nearly three-eighths of a mile. The descent is 21.5 feet in slightly more than one-half mile. The banks, from 20 to 30 feet high, are of clay over granite and afford splendid conditions for power development. Between the second and third pitches is a stretch of smooth water two miles in length.

Third Pitch is passed by means of a portage 100 yards long; the distance is the same by water. The descent is 17 feet. The river, which is five-eighths of a mile wide, is divided by an island; the banks are quite low near the water but rise beyond.

The section between the head of Kettle rapid and the foot of Gull rapid is also characterized by many swifts and rough waters. In the first mile, there is a fall of from five to eight feet; the stream is three-quarters of a mile wide and contains many islands; the banks in this part are very low. For the next three and one-half miles there is fairly smooth water leading to a portage two miles long, on the west side of the river. The descent from the head to the foot of the portage is approximately ten feet. Above the head of this portage occurs a series of small rapids and swifts for a distance of five miles, none of which need be considered in respect to power development. For the next four miles, the river is fairly smooth and contains many islands; the banks are from five to 15 feet in height but, in certain places, as low as two feet. A point in the river known as Moosenose is then reached, above which is a succession of swifts and rapids for a distance of three miles. The steepest section of these has a descent of nearly eight feet in three-quarters of a mile; owing to the width and the low banks of the river this, however, is not very suitable for power development. The succeeding seven miles of quiet water end at the foot of Gull rapid.

Gull Rapid

Gull rapid passes over granite, the rock appearing all along the banks. The four pitches, into which the rapid may be divided, are separated by swift and rough water which may be utilized to increase the natural heads. Unfortunately, the banks are very low in many places, rendering it impossible to

secure the full advantage for purposes of power development. From the head of the first pitch to the foot of Gull lake the river contains many islands.

First Pitch, which is passed by a portage on the north side of the river, shows a descent of 20 feet in a distance of 550 yards. Where two points project into the river it is only 1,000 feet wide; but above and below this narrow part, the river widens to 2,000 feet. The banks are 30 feet high, of granite and clay, and the head could be easily raised to 30 feet by drowning the swift and part of the rapids which extend above for a distance of three-eighths of a mile.

Second Pitch is also passed by a portage on the north side of the river, and shows a similar descent of 20 feet within a distance of 500 yards. On the north side, the river is divided into many channels by islands, but the main channel is 1,500 feet wide, with banks from 10 to 20 feet high. The possibility of the economic development of this pitch is questionable. In one of the north channels above the second pitch there is a succession of low cascades for three-eighths of a mile, at the end of which the foot of the third portage is reached.

Third Pitch, in the north channel, has a descent of 21 feet in a distance of 350 yards. The banks are very low, being almost on a level with the water at the head of the portage. In the boat channel, above the third pitch, there is a succession of low cascades three-eighths of a mile long; the banks are low as far as the foot of the fourth series of rapids.

Fourth Pitch shows a descent of 17 feet in three-eighths of a mile. In this stretch of the river there are many islands, and here also the banks are very low.

Gull lake is about one-half mile above the head of Gull rapid. It has very low banks which, in some places, are not more than three or four feet in height. It contains numerous islands, which, in some cases, restrict the channel to such an extent as to make the current quite strong.

For seven miles above Gull lake, there is a series of alternate swifts, smooth waters and rough waters, with a total descent of approximately 40 feet. The river has an average width of one-half mile, and the banks are of clay and granite, from 15 to 20 feet in height.

Overfall or Birthday Rapid.

Overfall rapid, which ends immediately above the section just described, is one-half mile long and has a descent of about 25 feet. The banks are 20 feet high, consisting of clay on rock. At the foot of the rapid, the river is divided by an island and the broader channel is 550 yards wide; at

Nelson River—Kettle Rapid

Nelson River—Bladder Rapid

the head of the rapid it flows in one channel, only 350 yards wide. Power development at this rapid seems quite feasible.

Above Overfall rapid is a stretch of smooth water, three miles in length; in the interval between this and Split lake—five or six miles upstream—is a series of rough waters and rapids with a total descent of about 30 feet. The steepest portion has a descent of 15 feet in a distance of one mile, but none of it seems suitable for economic development.

Above Split lake, as already stated, the character of the river changes considerably. The rapids are much better defined and have steeper descents; they are generally separated by long stretches of smooth water. Ascending the river from Split lake, the first chute encountered is Chain-of-islands chute.

Chain-of-islands Chute.—This chute occurs in the western channel, flowing around a large island at the head of Split lake. The descent is 4.5 feet in a distance of 300 yards. The channel is 200 feet wide, with rocky banks from 5 to 20 feet high. The head here may possibly be increased, but, unfortunately, the height of the banks above would not permit more than three or four feet additional.

Above this chute is smooth water for a distance of six miles, and, before the foot of Grand rapid is reached, the river is divided by several islands separated by very swift currents.

Grand Rapid has a descent of 20.1 feet, while the distance across the portage road is 160 yards. The river bends around the long narrow point across which the portage is made. Two sharp pitches or chutes, 600 feet apart, are succeeded by rapids below the second pitch. The total distance, following the river's course, is 1,300 feet. The river is 400 feet wide and the banks, which are of granite, 20 feet high, would render possible an increase of the head by an additional five or six feet.

A small rapid occurs two miles above Grand rapid, but the descent is only one foot in a distance of 20 feet. Both above and below this rapid the current is quite strong.

Manitou Rapid occurs in a very narrow section of the river. Although the descent in the rapid proper is comparatively small—about seven or eight feet in one-half mile—the fact that the river is only 400 feet wide favors power development. The granite banks are from 40 to 50 feet high. Above the rapid the current is quite swift and, except at short intervals, the banks remain fairly high, so that a head of at least 25 feet could be created without flooding much land.

Small Devil Rapid, three miles above the Manitou rapid, has a descent of three feet in 150 yards, and would probably be drowned out by creating a head at the latter rapid. At the head of Sipiwesk

lake, the river is divided by a large island and the next three rapids, namely, Chain-of-rocks, Red Rock and Over-the-hill, are situated in the eastern channel.

Chain of Rocks Rapid has a descent of 1.5 feet in a distance of 20 feet. The channel is 1,200 feet wide, with a chain of large rocks extending across it. The banks are from 10 to 20 feet high at the chute but very low above it, thus rendering it impossible to raise the head to the height necessary for the development of power.

Red Rock Rapid may be divided into four sections,—(1) the rapids below the lower canoe portage, (2) the chute at the lower portage, (3) the swift between the two portages, (4) the chute at the upper portage. The descent in the first section is about three feet in one-quarter of a mile while, in the other three sections above, it is 8.8 feet in a distance of 1,400 feet, giving a total descent of 11.8 feet. At the lower portage, the channel narrows to approximately 700 feet while, above and below, it is 2,000 feet wide. The banks are of granite and clay and from 20 to 50 feet high. A half-mile above Red Rock rapid is another small rapid with a descent of 1.3 feet in 200 yards. As the banks at this small rapid are fairly high it could be utilized to increase the head of Red Rock.

Over the Hill Rapid flows around a point and has a total descent of 9.5 feet; it consists of a chute, succeeded by a very rough rapid. Along the channel it measures nearly 900 feet, but the distance across the point, at the canoe portage, is only 260 feet. The banks, composed of clay over rock, are from 10 to 20 feet in height. The channel, at the chute, is only 800 feet wide and is divided by a fair-sized island situated in midstream.

Although the distance between Red Rock and Over-the-hill rapids is comparatively short, it is doubtful if they could be combined, as the banks between the two rapids are very low in several places. However, above Over-the-hill rapid, the current is strong and the descent, which averages from four to five feet per mile, could be utilized to increase the head at the latter rapid by several feet; but here, also, the banks are very low and this increase could not be more than three or four feet.

Bladder Rapid consists of a chute at the island where the York boats are portaged succeeded by heavy rapids extending over a distance of 400 yards. The total descent in these two sections is 8.3 feet; below this rapid is another stretch of swift water and rapids, 500 yards long, with an additional descent of possibly three feet. The width of the river at the canoe portage is 400 yards, but the stream is divided into two channels by a large island. The banks, consisting of clay over granite, are from five to fifteen feet high.

Nelson River—Ebb-and-Flow Rapid

Nelson River—Sea Fall (East Channel)

Whitemud Fall offers Favourable Prospects

This fall occurs where the river is divided into many channels by islands. It comprises two parallel chutes, flowing in distinct channels, whose waters unite to form the lower pitch and rapids below. There are two parallel portage roads at this fall and the difference of levels between the head and foot of the shorter one, which covers practically the total descent, shows a fall of 29.8 feet. The distance across the short portage is 500 yards but, following the channel, the distance between the first and last pitches is 700 yards. Below this chute is a stretch of very rough water. The channel in the lower part is 200 yards wide, with rocky banks from 40 to 50 feet in height, very steep on the west and perpendicular on the east side.

Ebb-and-flow Rapid is four miles above Whitemud fall, where the river is still divided into numerous channels by islands. The descent is 9.6 feet in a distance of 2,000 feet. The channel expands at the middle of the rapid but narrows to 500 feet at both the head and foot. The rocky banks are from 10 to 15 feet high.

Pipestone Fall is situated three miles above the head of Pipestone lake, in one of the channels formed by islands. It comprises chutes and rough waters, covering a distance of 50 yards and having a descent of 8.7 feet. The channel is 200 feet wide, with rocky banks from five to ten feet high at the head of the rapid, and from 15 to 20 feet in height at the foot.

At two miles, five miles and five and a quarter miles, respectively, above Pipestone fall, are small swifts and cascades, having descents varying from three-quarters of a foot to one and one-half feet.

Jackpine Rapid occurs in the east channel, six miles above Pipestone rapid. The descent is 4.6 feet in 125 yards. The rapid is divided into small channels by rocks and, at the head, the total width is 100 feet. The banks are of granite, from 10 to 20 feet high. There are several swifts, with descents of three-quarters of a foot or less between Jackpine rapid and The Four chutes.

The Four Chutes are situated seven miles above Jackpine rapid, in the east channel, and have a descent of 4.4 feet in 140 yards. The banks are of granite, five feet in height.

Sea Fall, eighteen miles below Norway House, is in the east channel, and has a descent of 5.1 feet in a distance of 50 yards. The granite banks are only three or four feet in height.

The total descent between Playgreen and Cross lakes could be utilized by a power-development at the Whisky Jack portage, where the whole flow of the river might be used. The head at this point

would include all the descents between the head of Sea fall and the foot of Pipestone rapid. The sum of the descents in Pipestone fall, Jackpine rapid, The Four chutes and Sea fall is 22.8 feet; the descents in the intervening short swifts and cascades give an additional 7 feet, while the swift current throughout this channel would add another 5 feet, making a total descent of at least 35 feet from the head to the foot of Whisky Jack portage.

DISCHARGE MEASUREMENTS OF NELSON RIVER, AT MANITOU RAPIDS

Date	Discharge Sec.-ft.	Date	Discharge Sec.-ft.
1914		1914	
July 18	103,736	August 15	91,928
" 25	87,088	" 17	92,775
August 3	94,084	" 21	94,861
" 4	92,083	" 24	88,931
" 4	94,508	" 24	91,985
" 7	96,179	September 5	87,542
" 8	96,228	" 7	89,956
" 10	95,043	" 7	91,806
" 11	94,206	" 24	90,857

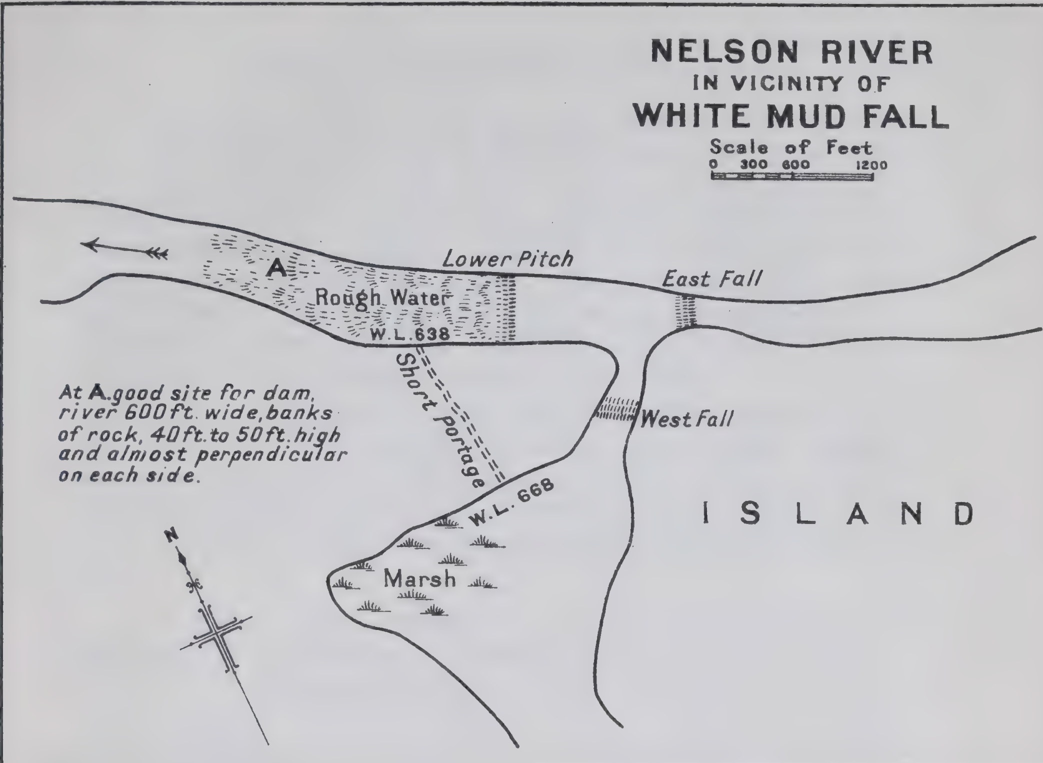
Burntwood River

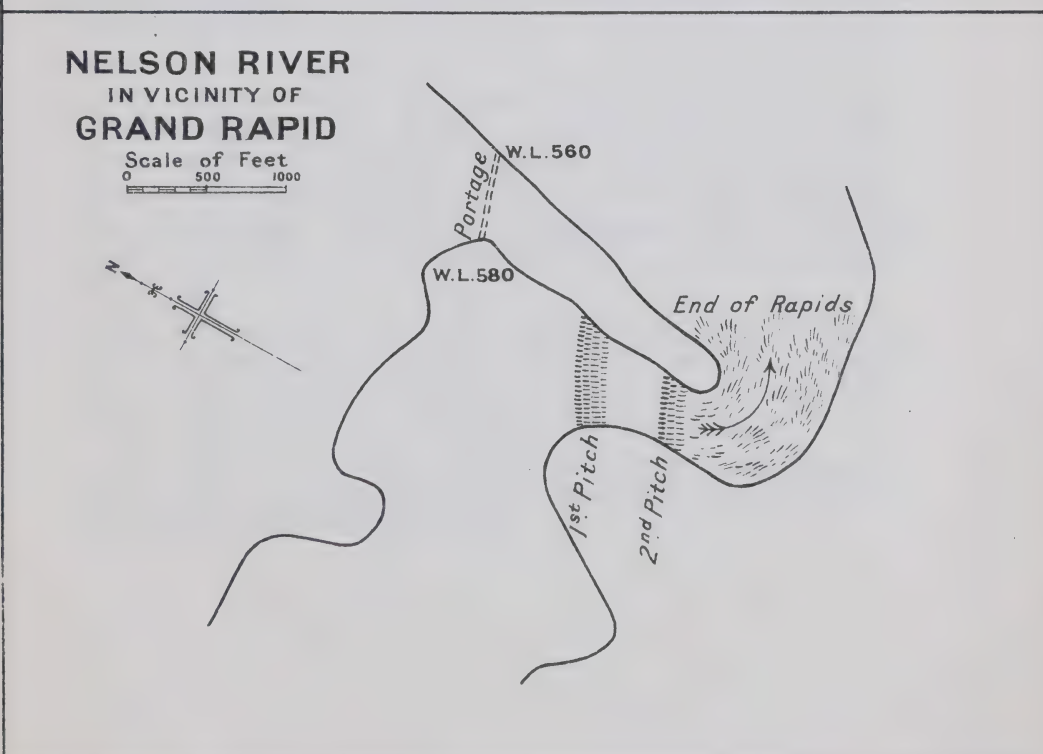
Burntwood river has its source in Burntwood lake. Carrot portage, about 18 miles below the outlet, is at an eight-foot fall. It is on the south side and not far below this the stream enters a rocky gorge, in which, at Eagle rapid, is another fall of eight feet.

The timber near the river is chiefly poplar, but, a short distance back, it is Banksian pine and spruce, all of which is very small. Flathill portage, three miles below Eagle rapid, is situated near a fall of ten feet. The granite ledge, which crosses the river here, is seen on each side rising in a high ridge 50 feet above the clay terrace. For a short distance below Moose portage the valley is not deep, but at Clay portage, three miles below Flathill portage, the stream falls 25 feet into a much deeper channel, which, for six miles, has scarped banks. The banks are nearly 40 feet in height and are composed of sand and gravel, with a bed of clay on the surface.

Series of Rapids and Falls

At Driftwood rapid, 17 miles below Clay portage, are two falls of four and five feet, respectively, flowing over red granite gneiss. A mile below this rapid, at Grindstone portage, the river again falls over red gneiss. Four miles below Grindstone it turns to the east and four falls occur at intervals of less than a mile, making a total descent of approximately 40


NELSON RIVER
IN VICINITY OF
WHITE MUD FALL
Scale of Feet
0 300 600 1200
Lower Pitch
East Fall
A
Rough Water
W.L. 638
Short Portage
West Fall
At A good site for dam, river 600 ft. wide, banks of rock, 40 ft. to 50 ft. high and almost perpendicular on each side.
W.L. 668
ISLAND
Marsh
N


NELSON RIVER
IN VICINITY OF
GRAND RAPID
Scale of Feet
0 500 1000
W.L. 560
Portage
W.L. 580
N
End of Rapids
1st Pitch
2nd Pitch

feet. The first is a fall of seven feet, the second of eight feet; the third, Leaf rapid, is a descent of eight feet, and the last, Gate rapid, of 17 feet. Below Gate rapid, the river enters a deeper valley. The banks are composed of sand and clay, and, before Threepoint lake is reached, they attain a height of nearly 30 feet. In this intervening stretch there are several small rapids. The last rapid, before reaching the lake, is called Moose-nose rapid, where the channel is constricted by an outcrop of gneiss. Below this section the channel broadens and the current is sluggish, except at a few points.

Farther downstream, the river flows in a valley from 60 to 80 feet deep, and, before entering Waskwatin lake, becomes sluggish, having low banks covered with poplar and willow. At the outlet of this lake Waskwatin fall descends 20 feet over gneiss. The portage, on the north side, is 220 yards long, crossing a hill covered with soft clay.

Some Heavy Descents

Three-quarters of a mile below Waskwatin fall is Taskimg-up portage, 320 yards long, passing a heavy rapid, where the water descends 50 feet over a ridge of gneiss. Thence to Opegano lake, the river banks usually ascend in easy slopes, although, here and there rugged, rocky cliffs overlook the water and ridges of gneiss cross the channel, forming rapids.

For a distance of two miles below Opegano lake, the river flows between steep, clay banks, 30 feet or more in height, to Waskatigow portage, which is four hundred yards long and passes a rapid with a descent of 30 feet. Below this rapid the river has steep, clay-covered banks, 60 feet high. One mile below Waskatigow rapid, is Kepuche rapid; it has a descent of three feet and flows in a narrow channel over a ridge.

One and one-half miles farther downstream is Wapishtigau fall, with a descent of 15 feet, where the stream is crossed by a ridge of gneiss. Two miles below this fall, the river expands into Birch lake; this is merely a long, wide and sluggish part of the river.

Two miles below Birch lake, immediately above the mouth of Manasan river, is Manasan fall, where a picturesque cataract descends about 20 feet over a ridge of gneiss.

Grass River

Cranberry and Elbow lakes form the headwaters of the Grass river. Four miles below Elbow lake is a rapid with a descent of 15 feet; past this, on the west bank, is a portage 160 yards in length.

Three-quarters of a mile farther downstream is another rapid, with a descent of 6 feet. Five miles farther there is a short rapid between steep banks of diorite. A mile below this rapid, the river expands into a small lake, and, for the next eight miles, flows eastward until it empties into the west end of Reed lake.

A mile below Reed lake is a rapid with a descent of 3 feet, flowing over a ridge of massive, reddish granite.

Wekusko Fall

Situated at the head of Wekusko lake, Wekusko fall has a total descent of 45 feet, falling over gabbro. Wekusko lake, which extends eastward from the foot of the fall, is a beautiful expanse of moderately clear water, with rugged, rocky shores.

Two miles below the mouth of Wuskatasko (or Carrot) creek, there are three heavy rapids, past the upper two of which are portages, 90 and 70 yards in length, respectively.

About 14 miles farther down there are three rapids with falls of twelve, fifteen and eight feet, respectively, over gray or reddish gneiss. The second and third of these rapids are known to the Indians as Kanistota (or the "Two") rapids.

For ten miles below Kanistota rapids, the river has a sluggish current flowing between sloping banks of light-gray clay, wooded with white and black spruce and Banksian pine. Then come Wapikwachew (or White Forest) rapid and, three miles and a half down the stream, Stikago (Skunk) rapid. A mile and a half beyond, is Wapishtigau (Whitewood) fall, one of the highest on the river, where the water falls 40 feet over a ridge of gneiss.

For three miles farther, to the mouth of Metishto, the river continues to flow with decreasing current, and is interrupted by two slight rapids. Thence, to Setting lake, the stream is wide and the current is more sluggish.

At the outlet of Setting lake, Grass river is broken by Golden Eagle rapid, which has a descent of 12 feet. Below this rapid, the river opens into another small lake, four miles in length. At the foot of this lake is Lynx fall, with a descent of 43 feet, passing, first, over an abrupt fall, below which is a steep, broken rapid flowing in a narrow, rocky channel.

Below Lynx fall, the river flows north-north-eastward for 23 miles to the south end of Paint lake; for the greater part of the distance it is without appreciable current. Its banks usually rise in easy slopes to a height of about 100 feet, and consist of rocky ridges of gneiss covered with a shallow deposit of soft, brownish clay without pebbles or boulders. The summits and sides of these hills are, as a rule, wooded with small poplars, but, close to the banks of the stream, there are scattered groves of large white spruce.

Hayes River

From a water-power standpoint this river can conveniently be divided into three sections: (1) From its mouth to Fox river; (2) from the mouth of Fox river to "The Rock," and (3) above "The Rock."

In the first-mentioned section, which extends for a distance of 90 miles above its mouth, the Hayes is quite wide; the current, which is much slacker than in the section above, shows a very gradual descent. Low banks are common and power development is practically impossible.

(2) From the mouth of the Fox to "The Rock," a distance of about 35 miles, is, possibly, the best part of the river for power development, although, in each case, heads would have to be created by dams. The total descent observed by aneroid is 285 feet, or an average of more than eight feet per mile. The banks, with few interruptions, are high, and heads of from 30 to 40 feet could easily be created. This part of the river has a fairly uniform width of approximately 250 feet, and, as already stated, the entire head for power development would have to be created by dams. However, these could undoubtedly be constructed at several sites, selected after careful surveys. At 4, 7, 20 and 23 miles below "The Rock," there are stretches of rough water or small rapids; each is from one-quarter to one-half mile long, with a descent of from three to four feet. Good sites for dams might be found at these rapids.

The third section, above "The Rock," is lengthy, but over 75 per cent of it consists of lakes. The stretches of river between the different lakes are short and the descent comparatively steep. Unfortunately, most of the different concentrated descents are of less than 10 feet and to combine them is not feasible, owing to the low banks.

The discharge of the Hayes river, metered on August 5, 1913, at a point four miles below "The Rock," was 3,265 cubic feet per

second. The width at this point was 252 feet, the maximum depth seven feet, and the greatest mean velocity in any one section 3·45 feet per second.

"The Rock" is the lowest portage on the river, and between it and Swampy lake, 35 miles upstream, the descent occurs in short rapids; these are not very steep but the current between them is strong. The highest rapids and falls are situated at the following points:

"The Rock" Fall has a descent of 5·1 feet in 80 yards, flowing over solid granite. An island divides the river at this point; each of the two channels is 100 feet wide, and the sandy banks are 50 feet in height.

Rapid, one mile above "The Rock," has a descent of three feet in a distance of 200 yards.

Whitemud Fall, situated three miles above "The Rock," consists of a chute, 50 yards long, with a descent of 4·3 feet, and a shorter chute 50 yards above, with a descent of ·8 foot; the total descent is 5·1 feet in a distance of 100 yards. The river is 300 feet wide and contains a small, rocky island situated in midstream, at the lower fall. The rocky banks are from four to five feet high on the west side and ten feet or more on the east.

Rapid, five miles above "The Rock," has a descent of 3 feet in 100 yards. The river is 200 feet wide and the banks four feet high, gradually rising in the distance.

Chute, seventeen and one-half miles above "The Rock," has a descent of 3 feet; below it is a stretch of rapids 300 yards long, with an additional drop of 3 feet, giving a total descent of 6 feet.

Rapid, eighteen miles above "The Rock," extends over a distance of 175 yards and has a descent of 3 feet.

Rapid, eighteen and one-quarter miles above "The Rock," has a descent of 5 feet in 100 yards. At the foot of this rapid, which falls over rock, is a small island. The river is 150 feet wide, with low banks, gradually rising to a height of eight or ten feet.

Rapid, nineteen miles above "The Rock," has a descent of 4 feet in 100 yards. The river is 150 feet wide; the banks on the west side are four feet high but on the east much lower.

Rapid, nineteen and one-half miles above "The Rock," has a descent of 5 feet in 400 yards.

Rapid, nineteen and three-quarter miles above "The Rock," has a descent of 3 feet in 100 yards.

Chutes and Rapid, twenty and one-half miles above "The Rock," are passed by two short portages. The lower is at a chute, which

has a sheer fall of 5 feet over a ledge of rock, where the river is divided into two channels by a small island. Each channel is 100 feet wide with banks from two to three feet high. Immediately above this is a stretch of 100 yards of smooth water, beyond which rapids, having a descent of one foot, extend for 100 yards to the foot of the upper portage. The river, in this portion, is 200 feet wide, with banks three feet high. The upper chute has a descent of 5 feet, giving a total fall of 11 feet within 200 yards.

Twenty-one and a half miles above "The Rock" is a small chute with a fall of 2 feet.

Rapid, twenty-two miles above "The Rock," has a descent of 6 feet in 300 yards; above it is a sharper descent of 4 feet within a distance of 80 yards, over a ledge of rock. The total descent of 10 feet occurs within a distance of approximately 450 yards, in a part of the river where the banks are low.

Muskeg Rapid, twenty-three and a half miles above "The Rock," occurs where the river is divided into several channels by islands; it has a descent of 8 feet in 300 yards. The rapid flows over a bed of rock, with low banks on each side.

Chute, two and one-half miles above Muskeg rapid, descends 6.8 feet in 100 yards, and is succeeded by a rapid having a descent of 3 feet in 150 yards. At the chute the river is divided into several channels by islands; the banks are low, rocky and, in many places, swampy.

Chute, four and one-half miles above Muskeg rapid, has a descent of 3 feet in 50 yards.

Chute, five miles above Muskeg rapid, occurs where the river is divided into at least nine channels. The descent is 4 feet in 70 yards. The banks are three feet high, rocky and swampy.

Rapid, five and one-half miles above Muskeg rapid, has a descent of 5 feet in 110 yards. At this point also the river is divided into several channels. The width of that where the portage is made is 200 feet; the banks are very low, rocky and swampy.

Chute, five and three-quarter miles above Muskeg rapid, has a descent of 2 feet over a ledge of rock. One hundred yards below the chute a short rapid descends one foot in 25 yards.

Rapid, six and three-quarter miles above Muskeg rapid, is really a succession of small rapids over boulders, extending for a distance of one mile. It has a total descent of 8 feet, but the banks are very low and marshy.

Rapid, eight and one-quarter miles above Muskeg rapid, flows over boulders and rock. It has a descent of 2 feet in 100 yards.

Rapid, eight and one-half miles above Muskeg rapid, has a descent of 2 feet in 50 yards.

Swampy lake is about four miles above the last rapid. Several swifts flow over boulders between the islands in the wide, lake-like channel situated immediately below the foot of the lake. None of these has an appreciable descent, and the banks are very low, averaging about one foot in height.

Between Swampy lake and Knee lake, there are four rapids of importance.

Yellowmud Rapid, four miles above the head of Swampy lake, has a descent of 5 feet in 200 yards. The river is 500 feet wide at the head of the rapid, narrowing to 200 feet at the foot, with rocky banks, five feet in height.

Lower Drum Rapid, three-quarters of a mile above the Yellowmud, has a descent of 10 feet in 500 yards. It is succeeded, at 100 and 200 yards below, respectively, by two small rapids, each of which has a descent of one foot in 50 yards. The rapid flows over boulders, and the river is 250 feet wide; the banks, consisting of boulders and soil, are from four to five feet in height.

Middle Drum Rapid, one and one-quarter miles above the Lower Drum, has a descent of 7 feet in 200 yards, but the distance over the portage is only 180 yards. The rapid flows over boulders and broken rock and is succeeded, at one-half mile and three-quarters of a mile, by two small rapids with descents of one and a half feet and one foot, respectively. At the larger rapid, the river is 150 feet wide, with banks of boulders and soil four to five feet high.

Upper Drum Rapid, three-quarters of a mile above the Middle Drum rapid, may be divided into two parts. The upper has a descent of 9 feet in a distance of 170 yards, and consists of two chutes, separated by sluggish water. The lower part is a continuous rapid, 150 yards long, with an additional descent of 3 feet. The river is 200 feet wide, with rocky banks five feet high.

Between Knee lake and Oxford lake, five rapids or falls occur:

Trout Fall, three miles above Knee lake, has a descent of 10·8 feet in 750 feet, but most of the descent is concentrated in a sheer fall. The river is divided by two islands; the widest channel is only 75 feet wide. The banks are very low, both above and below the fall.

Rapid, one mile above Trout fall, has a descent of 8 feet in 300 yards. This section of the river contains many islands and the banks are very low.

Rapid, four and three-quarter miles above Trout fall, has a descent of 2 feet in 100 yards. The banks, at this point, are only two to three feet above water.

HAYES RIVER—KNIFE RAPID

HAYES RIVER—TROUT FALL

Knife Rapid, five miles above Trout fall, has a descent of 3 feet within 50 yards. One hundred yards above it is another small rapid with a descent of 2 feet in 30 yards, giving a total descent of 5 feet in 180 yards. The banks are very low and swampy. Numerous islands divide the river into several channels, the widest of which is 150 feet.

Rapid, seven miles above Trout fall, has a descent of 2 feet in 100 yards. The banks here also are very low, and the river is divided into many channels.

Between Oxford lake and Windy lake, there are four small rapids:

Rapid and Chute, two and one-half miles above Oxford lake, have a descent of 6·5 feet in 100 yards. The river is divided by an island and each of the two channels is 50 feet wide. The banks above the rapid are very low.

Rapid, three and one-half miles above Oxford lake, has a descent of 2·75 feet in 20 yards. The rapid flows over a ledge of rock and the stream is 150 feet wide, with low banks.

Rapid, four miles above Oxford lake, with a descent of 2 feet in 70 yards, is similar in other respects to the preceding rapid.

Rapid, four and one-quarter miles above Oxford lake, with a descent of one and a half feet in 70 yards, is otherwise similar to the preceding two rapids.

There are no concentrated descents between Windy and Pine lakes but, above Pine lake, four of these may be noted:

Rapid, three miles above Pine lake, has a descent of 7 feet in 200 yards. The river is 100 feet wide, containing a rocky island near the foot of the rapid. The rocky banks are 75 feet high at the rapid, but are too low, on the west side above the rapid, to raise the head materially.

Rapid, seven miles above Pine lake, has a descent of 3 feet. The river is 50 feet wide, with rocky banks from 40 to 50 feet high.

Rapid, eight miles above Pine lake, has a descent of 5 feet in 150 yards. The river is 150 feet wide; the banks are high and rocky on the west side, but only three feet high on the east. While the banks above this rapid are very low, an increased head might be obtained by building a dam at a point one-quarter mile below, in a cañon-like part of the river, where the current is very swift and the banks high, rocky and perpendicular.

Robinson Fall, seventeen miles above Pine lake, is the most important power site on the upper section. Although its position on the upper part of the river gives it a smaller flow of water than is available at the sites in the lower portion, yet the high head obtain-

able at this point counterbalances this disadvantage to a great extent. The total descent here is 56 feet, and occurs at a bend in the river. The portage road, which cuts across this bend, is three-quarters of a mile long but the distance between the head and foot of the fall could be shortened. At the head of the fall, the river is 100 feet wide, and the natural head of 56 feet could be raised easily by several feet.

For two or three miles above Robinson fall, the width of the river is about 200 feet; the stream then expands, at its extreme head, into three narrow lakes, practically continuous.

CHAPTER VI

Saskatchewan River*

The North Saskatchewan and South Saskatchewan rivers, uniting at the forks, form the Saskatchewan river, which, after traversing part of the provinces of Saskatchewan and Manitoba, empties into the north-western part of lake Winnipeg.

The river between Cedar lake and lake Winnipeg may be described in detail as follows:

Grand rapid occurs in a large bend where the river is about 1,300 feet wide. It affords good conditions for a development with a head of 80 feet.

Between Red Rock and Grand rapid, the river is from 600 to 900 feet wide. The banks steadily decrease in height as one ascends the river.

At Red Rock rapid, the total fall is from 7 to 8 feet. The shores vary from ten to fifteen feet in height, and rock is visible everywhere.

A half mile below Cross lake, a barrier ridge of limestone crosses the bed, forming a shallow rapid one-half mile in length; this has a fall of 7 feet. The stream is divided into three channels by two islands. Only the south channel is of any considerable width, and all three are very shallow, averaging less than four feet, and only two feet in depth on the ledges. Both islands rise to less than five feet above the water. They are covered with scrub and hay land and all bear evidences of being submerged at high water. The main banks are about seven or eight feet high, gradually rising from the river to probably 15 feet in 1,000 feet or more.

At the inlet of Cross lake it falls over a rocky ridge. The fall in this rapid (the Demie-charge) is approximately 7 feet, evenly distributed; the width of the stream is 900 feet. The land in the immediate vicinity of the rapid is only from two to seven feet above the water, and is covered with dense woods, principally spruce, jack-pine and poplar.

At Anchor point, three miles below Flying Post rapid, the rock rises vertically to a height of almost 20 feet from the water, and is 35

*The data for the second half of this chapter were contributed by the Water Power branch of the Department of the Interior.

feet high a short distance back. On the left a similar rocky ridge is observed, extending to the northward.

One half mile below the Narrows, Flying Post rapid falls 4 feet, approximately, in three-quarters of a mile, flowing very swiftly over a shallow, rocky bed.

Cedar lake is nearly 42 miles in length, measured from east to west; the main portion is from 15 to 20 miles wide. The shores and basin are entirely of rock, with the exception of the deposit from the Saskatchewan at the upper end.

Between the forks and The Pas, the river may be described as follows: A long series of shallow rapids begins not far below the forks, the last one of which is the Squaw rapid, 125 miles down.*

Along this portion of its course the river is very winding, and, in places, forms great bends. For the first 90 miles it averages about 1,000 feet in width, flowing through a valley from 150 to 200 feet deep and about a mile wide. In general, a high cut bank of sandy clay loam faces a low flat sloping up gradually to a bench. Occasionally the valley narrows to a width of from 2,000 to 3,000 feet. In this stretch, the current is swift, with many rapids, the descent per mile for the 90 miles averaging about three feet. The river bed and the shores are composed of gravel and large boulders but no bed rock is exposed.

In the next 30 miles, the river expands to from 1,300 feet to a mile and a half, with many large islands in the channel. The banks are very low and flat and no bench is noticeable from the river. The current is slower, with few rapids, and the descent per mile is about 1·2 feet. The bed and banks of the river are composed of light, sandy clay loam, which is easily eroded and transported by the current, thus forming sand bars.

About five miles above Squaw rapid, the banks begin to close in again, and a valley similar to that in the first 90 miles below the forks appears. Rapids become more numerous while the boulder and gravel formation is again seen. In this five miles, the fall averages about four feet per mile.

For the first 90 miles below the forks, the timber is mainly poplar and balm of Gilead fir, with some spruce, while below this, and especially on the large flats, spruce of good size predominates.

Immediately below Pasquatina point, 135 miles from the forks, is the Sipanok, or the Underground river, as the name implies. This channel permits the waters of the Saskatchewan to pass over into the Carrot river, and thence back to the main stream at a point situated

* See Appendix I for descents and power sites.

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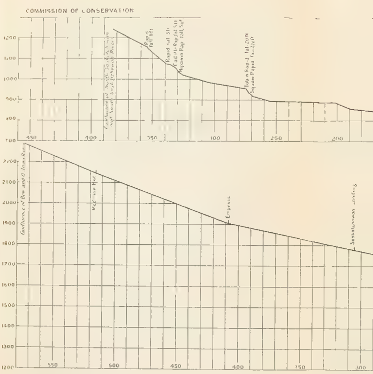


a few miles above The Pas. This new watercourse has opened up more each year, cutting out the soft banks, until quite a volume of the Saskatchewan water passes through it. During high water a fair-sized tug, drawing four feet, has made the trip by this route.

Four miles below the Sipanok, or 139 miles below the forks, the Saskatchewan has overflowed its north bank and formed a junction with the Sturgeon-weir river, thence to Cumberland lake. This leaves the original river bed practically dry for a distance of more than 50 miles, to the mouth of the Bigstone river, the first outlet of Cumberland lake.

Heavily Wooded Banks

From Squaw rapid, the river traverses the entire distance to Cedar lake (225 miles) through an extensive flat region of lake and marsh. Nowhere do the banks rise to any considerable height above the water. In most places, lakes or marshes are to be found within 100 yards of the river. The banks are, for the greater part, heavily wooded. The flood waters overflow into a great tract, becoming lost probably 40 or 50 miles from the river. During early summer these basins fill up, while, later in the year, the flow is reversed, the water finding its way back into the main stream. The two-fold function of this area is to act (1) as a vast storage basin, regulating the flow of the lower river, and (2) as a settling basin. Much of the sediment is deposited here. Lakes, which 15 years ago had six feet or more of water in autumn, have now less than two feet. The flat, mud shores, exposed to view, are strewn with driftwood brought down by the river.

Valuable timber is found a short distance above The Pas, but thence to Cedar lake the growth is stunted; while a dense growth occurs around both Cedar and Cross lakes, the timber found below this is chiefly second growth.

Great Variation In Flow

The chief characteristic of the rivers that rise in the Rockies, is the extreme variation between maximum and minimum discharge—sometimes as great as 200 to 1—and the sudden rises that occur in these streams. The North Saskatchewan and South Saskatchewan receive the greater portion of their flow from the mountains and are affected by extremes of temperature in the high altitudes. In these rivers and in the main Saskatchewan the discharge varies greatly during the year; high water and floods, due to warm rains and hot weather in the mountains, usually occur during July and August, while the low flow occurs during February and March. This also applies to their mountain tributaries and consideration of this is a factor of vital importance

in designing hydro-electric developments on these streams. At The Pas the range between these two periods is ordinarily some 15 feet, which, at Grand rapid, is gradually lessened, to from four to five feet, with an extreme of some six feet. During the spring break-up, the field ice of lake Winnipeg occasionally becomes jammed at the mouth of the river, damming the outlet and causing rise at the lake of from 12 to 15 feet.

The Saskatchewan is navigable above Grand rapid, the Hudson's Bay Company having at one period operated steamers as far as Edmonton. At present it is navigated by gasolene launches from The Pas to Cedar lake, also by steamer from The Pass to Cumberland lake. It is accessible by railway at The Pas and also by steamer at the mouth.

With the exception of The Pas, no important settlements are found in the lower reaches of the river. A Hudson Bay post is situated at Cedar lake, and a small settlement at Grand rapid.

Surveys of the River

In 1884 Dr. Otto Klotz made a traverse of the river. In 1909 a reconnaissance survey of the river was made from The Pas to lake Winnipeg by E. A. Forward, of the Public Works Department. The investigations made by the Water Power branch of the Department of the Interior comprise a reconnaissance power survey by the late William Ogilvie in 1911, a detailed survey by E. B. Patterson of Grand rapid and vicinity from lake Winnipeg to Cross lake in 1912, and reconnaissance survey from Prince Albert to Sipanok channel by C. H. Attwood, in 1914.

Run-off and Discharge

Precipitation.—No complete records of the precipitation in either the extreme western or eastern portion of the basin are available. The following table gives the precipitation at various points throughout the central portion, and in the Rocky mountains:—

Station	Length of record			Depth in inches
	Period	From	To	
Prince Albert	9 years	1903	1912	17.13
Saskatoon	9 "	1904	1912	14.45
Edmonton	28 "	1883	1912	16.43
Dunvegan	4 "	1905	1909	11.5
Macleod	22 "	1884	1912	12.58
Calgary	27 "	1885	1912	15.17
Banff	19 "	1891	1912	20.3

Discharge Measurements.—Float discharge measurements were made in 1909 by E. A. Forward at The Pas, and also at Grand rapid. These were followed by measurements made by the late William Ogilvie, in the year 1911, at Grand rapid. On August 8, 1912, a gauging station was established at Grand rapid by the Manitoba Hydrometric Survey, and on October 21, of the same year, a second station was established at The Pas. A summary of discharges at these stations is given on pages 127 and 128.

Opportunities for Storage

Three lakes are situated in the lower portion of the river system immediately above Grand rapid; the river flows through Cedar and Cross lakes, while Moose lake is a tributary to the north. The area of these lakes is as follows: Cross lake 39, Cedar lake 425, and Moose lake 513 square miles; total, 970 square miles. While storage on these lakes is possible, the projected reclamation of low lands in the vicinity of Cedar lake, through the lowering of the latter, would forestall storage possibilities. Investigation is also being made into the storage possibilities in the headwaters of the Saskatchewan river.

Assuming that the flow of the winter months, from October 1, 1913, to April 1, 1914, would be similar to that of the same period during 1912-1913, mean curve studies show that a storage of 305,000 million cubic feet would be necessary for a uniform flow of 32,000 second-feet. A one-foot storage on Cross, Cedar and Moose lakes would give approximately 27,000 million cubic feet, indicating that a storage of slightly over eleven feet would be necessary.

Water-power Available

An estimate of the power available at the three rapids is given below. The power available has been based on an 80 per cent efficiency, and is also computed,—(1) for an estimated minimum flow of 4,500 second-feet, and (2) for a flow of 20,000 second feet, this being the lowest monthly mean flow for the six highest months during each of the years 1913, 1914, and 1915, and the power as indicated refers only to this period.

No estimate has been made of the additional power available during periods of low flow through any storage system:—

Possible power site	Head in feet	Estimated horse-power on 80 per cent efficiency	
		Min. flow 4,500 sec.-ft.	Period 6 highest months 20,000 sec.-ft.
Demi-charge	15	6,100	27,200
Red Rock	15	6,100	27,200
Grand Rapid	80	32,600	145,000

The engineers of the Water Power branch and of the Public Works Department, are working out a project for power development at Grand rapids, which will make proper provision for navigation. While the Water Power branch already has considerable topographic and hydrographic information regarding this portion of the Saskatchewan river, it will be necessary to make further examination on the ground before coming to a final decision respecting the method of power and canal development. Arrangements are being made for this work at an early date.

The survey by C. H. Attwood, Water Power branch, shows six possible power sites between Prince Albert and Sipanok channel. The results are summarised below:

POSSIBLE POWER DEVELOPMENTS—SASKATCHEWAN RIVER

Power Site (miles below Prince Albert)	Head in feet	Estimated discharge in c.f.s.		Horse-power		Remarks
		Dependable for 8 months	Minimum	For 8 months (discharge of col. 3)	Minimum (discharge of col. 4)	
1	2	3	4	5	6	7
Cole falls Mile 29	28	2,500	1,000	6,363	2,550	Under construction.
Mile 38	40	6,500	2,400	23,640	8,730	
Mile 51½	40	6,500	2,400	23,640	8,730	
Mile 70	55	6,500	2,400	32,500	12,000	
Mile 84	40	6,500	2,400	23,640	8,730	
Mile 101½ ...	30	6,500	2,400	17,725	6,545	
Mile 161½ ...	60	6,500	2,400	35,455	13,090	Squaw rapids.

MONTHLY DISCHARGE OF SASKATCHEWAN RIVER, NEAR THE PAS, MAN.

(Drainage area 149,500 square miles.)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1913				
January			6,000*	.041
February			5,000*	.033
March			6,000*	.041
April			34,200*	.229
May	62,740	44,720	53,186	.355
June	57,970	44,190	50,346	.337
July	63,800	55,850	60,402	.404
August	63,005	54,790	58,084	.388
September (1-28)	55,055	33,060	45,000*	.30
October			25,000*	.17
1914				
January			6,000*	.040
February			5,000*	.034
March			4,500*	.030
April			25,000*	.167
May	58,100	41,100	44,400	.297
June	54,600	38,800	45,100	.301
July	59,600	54,900	58,394	.391
August	55,700	27,400	40,400	.270
September	27,400	23,500	25,210	.169
October	23,500	18,500	20,658	.138
November	25,200	9,600	17,200	.115
December	9,450	6,550	8,700	.058
1915				
January			4,500*	.030
February	5,330	4,745	5,163	.034
March	5,980	5,213	5,556	.037
April	49,925	5,980	24,583	.164
May	32,056	17,930	25,069	.168
June	56,350	35,050	44,904	.300
July	94,328	57,091	79,185	.530
August	100,317	80,720	94,697	.633
September	80,330	47,082	65,329	.437
October	45,624	25,105	34,141	.228
November			21,000*	.140
December			7,000*	.047
Year	100,317	4,745	32,519	.229

* Estimated.

MONTHLY DISCHARGE OF SASKATCHEWAN RIVER, NEAR HEAD OF GRAND RAPID, MAN.

Month	Discharge in second-feet		
	Maximum	Minimum	Mean
1912			
August (3-31)	62,000	47,000	52,000
September	66,500	61,250	64,500
October	74,000	39,500	62,750
November (1-25)	38,750	23,000	

MONTHLY DISCHARGE OF SASKATCHEWAN RIVER, NEAR HEAD OF GRAND RAPID, MAN.—*Continued*

Month	Discharge in second-feet		
	Maximum	Minimum	Mean
1913			
May (19-31)			45,300
June	48,500	45,500	45,800
July	56,000	46,500	50,900
August	56,750	54,500	55,300
September	53,000	40,400	46,900
October	39,950	25,100	33,100
November (1-11)	24,500	19,250	
1914			
May	48,500	24,700	32,200
June	36,500	28,500	32,700
July	48,200	35,200	42,200
August	54,600	26,600	40,800
1915			
January			*4,500
February			*5,000
March		5,080	5,850
April	20,454	5,660	10,041
May	22,414	16,572	18,913
June	38,298	17,682	25,621
July	67,060	39,320	53,380
August	80,638	66,330	74,162
September	83,266	66,622	75,601
October	65,308	30,998	47,563
November	30,706	15,610	20,590
December			*8,000
Year	83,266		29,102

* Estimated.

CHAPTER VII

North Saskatchewan River and Tributaries

The North Saskatchewan river traverses the great central prairies of western Canada and the southern portion of the wooded country between the Rocky mountains and Hudson bay. Rising in the Rocky mountains, it has its source in several branches fed by the glaciers of the eastern slopes. The head-waters are approximately 350 miles west of Edmonton and 1,100 miles west of Prince Albert, measuring along the river.

Leaving the foothills, and entering the plains, the tributaries flow rapidly between high clay and gravel banks. Portions of the streams are very tortuous.

For eleven miles below the mouth of the Brazeau, the North Saskatchewan continues its northerly course. In this distance, the current is very irregular but averages four and one-half miles per hour.

For a distance of ten and one-half miles below Rocky Mountain House, the west bank of the river is a low, alluvial flat, overlying quartzite gravel, and wooded, in most places, with spruce of fair size. The east bank is high in sections, showing escarpments of yellowish, coarse-grained sandstone, apparently horizontal.

Power Development Possible

There is a possible power site at the Rocky rapid, 75 miles west of Edmonton. In one of the first schemes contemplated, the total head would have to be created by a dam, as the descent is not very steep. Although there is rock underlying the river bed, it is covered to a considerable depth with gravel and sand; the rock forming the bank at this point is a soft sandstone and resembles cemented sand more than rock. The river flows through a wide valley formed by banks from 150 to 200 feet in height; in many places there are wide bottom lands, most of which are well timbered with spruce and poplar. To create a head of 50 feet a dam 1,800 feet long would be necessary. With an assumed low-water flow of 1,400 second-feet, nearly 8,000 theoretical h.p. would be available, but it is reported that the cost of development would be high.

Further investigations in connection with Rocky rapid and vicinity have revealed a more favourable power site in township 47, range 7, west of the fifth meridian, where a dam, 85 feet high, would have to be built. The river, for a few miles above and below this site, has a very swift current and a fall of about eight feet to the mile, with an average width of about 500 feet. The main valley is about 200 feet deep and nearly one mile wide on the crests. Steep river banks on one side generally alternate with low, flat banks on the other.

At the proposed dam site, a cut bank on the right, composed of layers of clay and sandstone, rises very abruptly to a height of 225 feet. The river channel lies at the foot of the right bank and is about 500 feet wide at high water. On the left bank, a flat recedes for 700 feet, and then rises in a moderate slope to a height of about 200 feet.

The main river, between Edmonton and the junction with the South Saskatchewan, 30 miles east of Prince Albert, is a swift, steady stream, having a uniform descent and an occasional rapid, flowing over a rough boulder bed, between banks of boulder-clay or hard-pan. There are, however, no steep pitches in any of the rapids; the greatest fall is three and one-half feet in 2,000 and occurs at the Crooked rapids, immediately above the forks.*

At Edmonton, and for 186 miles below, the river is narrow. A good channel is found throughout almost this entire distance.

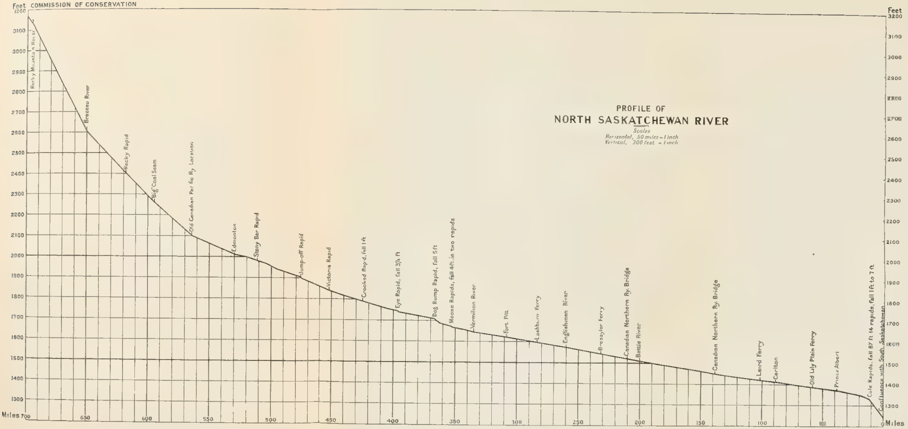
From Vermilion river to Prince Albert, a distance of 289 miles, there are no rapids, but shifting sand-bars are of very frequent occurrence. This section of the river is wide, varying from 1,000 to 4,000 feet, and contains numerous islands and several channels.

To obtain a clear idea of conditions in this drainage basin, it is necessary to describe the principal characteristics of the different portions of the area. The basin naturally divides itself into five sections.

Natural Divisions of Drainage Area

The first, or upper division, consists of the eastern slope of the Rocky mountains. While this portion of the basin is not the largest in area, it supplies the major portion of the drainage. In the glaciers and snow of the higher peaks, innumerable small streams rise and flow eastward, forming larger streams, which empty into the main river. These streams also are fed by the melting snow and by rains which fall in the mountains at all seasons of the year. Under these conditions the mountainous region frequently discharges a great

* For more detailed information respecting the rapids of this river see also p. 279 and profile facing this page.



COMMISSION OF CONSERVATION
PROFILE OF
NORTH SASKATCHEWAN RIVER
Scales
Horizontal, 50 miles = 1 inch
Vertical, 300 feet = 1 inch
Feet
Miles
Rocky Mountain House
Brazeau River
Rocky Rapid
"Big" Coal Seam
Old Canadian Pacific Ry. Location
Edmonton
Stony Bar Rapid
Jump-off Rapid
Victoria Rapid
Crooked Rapid, fall 1 ft
Eye Rapid, fall 3½ ft
Dog Rump Rapid, fall 5 ft
Moose Rapids, fall 4 ft. in two rapids
Vermilion River
Fort Pitt
Lashburn Ferry
Englishman River
Bresaylor Ferry
Canadian Northern Ry. Bridge
Battle River
Canadian Northern Ry. Bridge
Laird Ferry
Carlton
Old Lily Plain Ferry
Prince Albert
Cole Rapids. fall 87 ft 14 rapids, fall 1 ft to 7 ft
Confluence with South Saskatchewan

quantity of water into the streams in a short time. This is especially noticeable each spring when the mountains, for the most part bare of vegetation, are exposed to the sun, which melts the winter's snow quickly. Floods occur when this warm weather is accompanied by rain. The lower slopes of the mountains and the valleys are well wooded, and, to a considerable extent, offset the effects of warm weather. The streams in this division have a descent of from 20 to 100 feet per mile.

Well Covered with Forest

Below the mountain section are the foothills, constituting the second, and largest, division of the basin. Here the river flows easterly and northerly and is joined by numerous streams. The valley is deeper and more clearly defined. The country is hilly and rough but not as broken as the mountain section. The entire region has a fairly heavy precipitation and is well covered with forest. Large tracts of muskeg occur and, while they tend to make the drainage uniform, if well saturated, they offer less resistance to rapid run-off of heavy rains than bare hillside. The descent of the river in this section is from 5 to 20 feet per mile.

From near Edmonton to the mouth of the Vermilion river, the North Saskatchewan flows through a park-like country, with great areas of prairie. Few tributaries flow into the river and the drainage area of this third division is small. The valley is well-defined, with few flats along the river. The descent is over 1½ feet per mile.

The fourth section, from the Vermilion river to Prince Albert, is principally prairie, with occasional stretches wooded with small timber and second growth. The valley of the river is much wider and the stream itself expands into shallow reaches full of shifting sand-bars. Low-lying flats border the river for the greater part of the course. The slope of this section is one foot per mile.

The fifth and last division extends from Prince Albert to the confluence with the South Saskatchewan. It has a descent of 3½ feet per mile, occurring in a series of rapids. The valley is not as deep as in the two preceding sections, but the river channel is more clearly defined. The basin is fairly well timbered and contains very little prairie land.

Below the confluence the main Saskatchewan river is a chain of lakes and lagoons, surrounded by low-lying land and muskeg, covered with trees.

In the lower portion of the region traversed by the river the timber is chiefly soft wood of small size and of little value for structural purposes.

The river is normally shallow; near Prince Albert it is from 800 to 1,200 feet wide, and from 8 to 15 feet deep. In the rapids and swifts the shallowest water appears to have a depth of 5 or 6 feet in the mid-channel sections.

Flood Season

The flood season is divided into two distinct periods. The earlier, in April and May, is due to the ordinary freshets on the plains and carries the ice out of the river; the second, in June and July, results from the melting of snow in the foothills and mountains. The latter flood is much the greater and of longer duration. Occasional abnormal rises bring very heavy floods. At Prince Albert the water has risen 20 feet above normal level and at Edmonton it has risen 38 feet in a few hours.

The flow of the North Saskatchewan varies greatly throughout the year, although in the autumn and winter months it is nearly uniform. From September until March, it gradually decreases in volume; the three winter months, January, February and March, comprise the period of lowest water, on account of the frozen condition of the whole drainage basin.

During eight months of the year, a flow of approximately 6,000 cubic feet per second may be relied on.

The ordinary maximum flood discharge, occurring in July, appears to be about 80,000 cubic feet per second, but on June 28, 1915, a flood of 204,500 c.f.s. was recorded at Edmonton.

Discharge Measurements

Gauge readings on this river have been made at Edmonton for a number of years, during the open water season. In 1911 regular gauging stations were established by the Irrigation branch of the Interior, at Edmonton, Battleford and Prince Albert, and later at Rocky Mountain House and Rocky Rapids:

MONTHLY DISCHARGE OF NORTH SASKATCHEWAN RIVER, AT EDMONTON, ALTA.

(Approximate drainage area, 10,700 square miles)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1911				
May	21,755	6,568	9,238	.85
June	27,930	10,600	17,412	1.61
July	51,442	15,520	28,094	2.60
August	46,692	15,320	24,600	2.28
September	18,668	8,024	11,502	1.07
October	8,024	4,887	6,597	.61
November (1-10)	4,692	3,132	3,723	.34
December (6-31)	1,750	1,380	1,638	.152

MONTHLY DISCHARGE OF NORTH SASKATCHEWAN RIVER, AT EDMONTON, ALTA.—*Continued*

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1912				
January	1,402	1,164	1,255	.116
February	1,436	1,232	1,328	.123
March	2,620	1,062	1,316	.122
April	7,700	2,820	4,629	.43
May	16,200	4,770	11,926	1.10
June	35,150	6,180	18,242	1.69
July	74,100	15,000	13,900	1.29
August	70,300	13,900	26,444	2.45
September	23,750	7,350	12,864	1.19
October	8,460	5,595	7,162	.66
November	5,595	1,504	3,177	.29
December	1,980	1,266	1,680	.156
1913				
January	1,720	1,210	1,393	.129
February	1,560	1,230	1,313	.122
March	1,820	1,210	1,315	.122
April	27,000	1,900	8,227	.763
May	14,800	4,300	9,727	.902
June	29,700	12,100	19,780	1.830
July	29,700	16,000	21,439	1.990
August	32,600	9,700	18,505	1.720
September	15,400	5,700	9,430	.875
October	6,100	3,100	4,539	.421
November	2,950	1,770	2,357	.219
December	1,740	650	1,058	.098
1914				
January	1,450	968	1,213	.114
February	1,100	800	952	.090
March	1,300	975	1,134	.107
April	6,570	1,075	2,983	.281
May	15,000	3,950	9,064	.854
June	61,740	5,440	24,618	2.320
July	25,620	11,130	18,889	1.780
August	14,400	9,110	11,099	1.040
September	9,370	4,240	6,492	.611
October	5,840	3,130	4,558	.429
November	2,970	2,050	2,473	.233
December	2,350	700	1,102	.104
1915				
January	1,350	1,010	1,223	.115
February	1,120	1,040	1,079	.102
March	2,420	1,115	1,677	.158
April	4,700	2,220	3,323	.313
May	14,780	3,280	8,373	.788
June	185,560	17,420	39,272	3.70
July	90,200	26.670	42,661	4.02
August	33,150	18,260	23,554	2.22
September	18,600	6,690	10,294	.969
October	8,070	4.450	5,673	.534
November	4,450	2,230	3,013	.284
December	2,280	1,320	1,716	.162

MONTHLY DISCHARGE OF NORTH SASKATCHEWAN RIVER, AT PRINCE ALBERT, SASK.

Month	Discharge in second-feet		
	Maximum	Minimum	Mean
1910			
June (22-30)	23,985	13,148	16,600
July	18,600	12,100	15,346
August	18,600	10,630	13,904
September	20,100	10,280	12,609
October (1 and 8-31)	10,982	6,172	8,120
1911			
May (8-31)	17,020	7,070	9,817
June	22,000	8,460	14,828
July	42,200	17,500	25,956
August	41,400	18,500	25,682
September	25,800	10,385	16,438
October (1-29)	10,385	5,380	7,902
1912			
January	1,576	1,460	1,505
February	1,610	1,550	1,584
March	1,610	1,544	1,579
April	18,750	1,584	9,022
May	15,964	6,110	11,280
June	32,450	6,704	14,864
July	69,880	17,800	35,301
August	54,600	19,100	30,044
September	44,360	12,140	22,277
October	12,180	8,985	10,024
November	8,635	2,328	4,915
December	2,600	1,790	2,315
1913			
January	2,675	1,350	1,663
February	1,725	1,375	1,583
March	2,500	1,650	1,981
April	33,575	2,400	16,330
May	18,600	7,720	12,149
June	27,580	13,865	19,042
July	33,190	21,400	26,186
August	35,665	17,800	25,096
September	18,900	9,985	14,576
October	9,670	3,950	7,114
November	5,125	2,600	3,022
December	2,600	1,375	1,819
1914			
January	1,565	850	1,221
February	1,433	1,077	1,191
March	1,380	1,229	1,295
April	15,860	1,402	4,350
May	17,978	8,516	13,235
June	63,290	8,900	30,347
July	35,650	18,590	29,456
August	17,420	11,580	14,550
September	13,580	6,986	10,304
October	8,936	6,634	7,763
November	6,539	1,670	3,736
December	3,500	1,050	2,533
1915			
January	2,150	1,280	1,760
February	1,800	1,550	1,655
March	2,050	1,570	1,707
April	18,500	2,250	9,046

MONTHLY DISCHARGE OF NORTH SASKATCHEWAN RIVER, AT PRINCE ALBERT, SASK.—*Continued*

Month	Discharge in second-feet		
	Maximum	Minimum	Mean
1915—*Con.*			
May	10,700	4,820	7,003
June	42,660	9,940	25,023
July	186,546	33,200	60,224
August	36,430	21,850	28,129
September	24,460	9,150	14,999
October	9,190	6,030	7,653
November	6,010	2,620	3,896
December	2,880	1,700	2,238

NOTE.—As this stream is fed chiefly from the mountains, it was decided not to use the results obtained from the drainage area since they would be misleading.

MONTHLY DISCHARGE OF NORTH SASKATCHEWAN RIVER, NEAR ROCKY MOUNTAIN HOUSE

(Drainage area 4,050 square miles)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1913				
June (2-30)	17,240	9,150	12,347	3.06
July	21,040	8,300	13,456	3.34
August	22,750	7,330	13,550	3.36
September	11,730	4.460	7,417	1.84
October	4,810	2,210	3,100	.76
November	2,350	1,390	1,892	.47
December	3,580	830	1,630	.40
1914				
January	920	720	848	.21
February	830	650	729	.18
March	940	800	862	.21
April	1,750	900	1,114	.27
May	6,300	1,894	4,104	1.02
June	18,000	4,350	10,808	2.68
July	16,746	8,640	12,914	3.20
August	12,566	7,010	8,916	2.21
September	7,010	3,090	4,772	1.18
October	4,350	2,280	3,187	.79
November	2,322	1,040	1,753	.43
December	955	802	850	.21
1915				
January	875	785	833	.206
February	798	695	751	.185
March	847	627	681	.168
April	1,827	850	1,451	.358
May	9,052	2,052	5,934	1.465
June	129,700	7,180	22,894	5.653
July	36,325	15,760	22,562	5.571
August	27,325	13,600	16,753	4.137
September	12,400	4,625	6,964	1.720
October	4,925	3,120	3,686	.910
November	3,030	1,340	1,994	.492
December	1,435	1,310	1,364	.337

MONTHLY DISCHARGE OF NORTH SASKATCHEWAN RIVER, AT ROCKY RAPIDS

(Drainage area, 8,230 square miles)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1915				
January	1,360	1,100	1,257	.153
February	1,300	1,100	1,209	.147
March	2,350	1,050	1,569	.191
April	4,900	2,400	3,547	.431
May	23,000	3,700	9,519	1.157
June	190,500	19,100	43,550	5.292
July	94,200	24,860	41,094	4.993
August	42,240	17,780	24,549	2.983
September	21,360	6,800	10,906	1.325
October	7,625	4,705	5,717	.695
November	4,570	2,310	3,149	.383
December	2,320	1,410	1,782	.216

The North Saskatchewan river is regarded as a navigable stream between the confluence with the South Saskatchewan and Edmonton. It was navigated for many years by the Hudson's Bay Company's and other steamboats. Navigation usually opens toward the end of May or the first of June, in the high-water period, and continues until late in August, depending upon the rate at which the water falls to low level.

Cole Fall Development

A very important hydro-electric plant for the city of Prince Albert is now in course of construction on this river, at Cole fall, 26 miles east of that city. The plant is situated on secs. 30 and 31, tp. 49, rge. XXII, west second meridian, and the development comprises a 30-foot Ambursen dam, giving a head of 29·5 feet at low water and 23·5 feet at high water; a lock, 150 feet long and 40 feet wide, is provided at the south end of the dam. The power-house is designed to accommodate machinery with a capacity of 7,500 h.p., but the present installation will generate only 5,000 h.p., divided into two units of 2,500 h.p. The transmission line to Prince Albert follows the government road and will be about 28 miles long; 35-foot wooden poles, with fire-protected butts, are to be used; the 3-phase current will be transmitted at 33,000 volts to the receiving-station, on the north side of the river, adjoining a proposed auxiliary steam-plant.

Battle River

Battle river is from 50 to 200 feet in width and flows in a very tortuous channel. For the greater part of the course, the river is at the bottom of a deep and winding valley, although occasionally

Saskatchewan River—Grand Rapid

Saskatchewan River—Red Rock Rapid

it is but little below the level of the surrounding plain. The stream issues from Battle lake, 2,294 feet above sea, and flows eastward midway between the Red Deer and North Saskatchewan rivers, entering the latter one mile and a half below Battleford. From Battle lake, for a distance of 40 miles, it flows southeast in the bottom of a straight, well-defined valley, which averages one-half mile in width and 100 feet in depth.

At the Elbow, it turns N. 55° E., flowing for 19 miles in a gradually expanding valley. The river is still very tortuous, with stretches of quiet water, separated by short rapids, in which the bottom of the channel is covered with pebbles and boulders. At the eleventh base-line, the river turns sharply and flows northward for 16 miles to the mouth of Iron creek.

One of the power sites on this river, examined in the interest of the municipality of Battleford, is situated six miles above the town. A dam, approximately 1,500 feet long, would be necessary to obtain a head of 65 feet. However, the cost of construction was considered excessive.

In 1911, a gauging-station was established on this river at Battleford, Sask., by the Irrigation branch of the Department of the Interior. The following is a summary of discharges since that date:

MONTHLY DISCHARGE OF BATTLE RIVER, AT BATTLEFORD
(Drainage area, 11,850 square miles)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1912				
April (14-30)	3,522	908	1,396	.118
May	842	506	599	.051
June	739	496	585	.049
July	4,030	555	1,143	.096
August	2,350	995	1,560	.132
September	1,380	990	1,179	.099
October	1,003	586	727	.061
1913				
January	130	20	57	.005
February	100	30	58	.005
March	150	25	75	.006
April	5,736	1,366	3,175	.268
May	1,878	580	990	.083
June	586	330	447	.038
July	718	400	512	.043
August	580	320	457	.038
September	532	420	468	.039
October	460	275	365	.031
November	325	130	194	.016
December	150	38	101	.008

MONTHLY DISCHARGE OF BATTLE RIVER, AT BATTLEFORD.—*Con.*

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1914				
January	39	24	29	.0024
February	24	20	21	.0018
March	33	20	22	.0019
April	1,071	37	446	.0376
May	1,970	805	1,429	.121
June	3,630	760	1,680	.142
July	2,873	790	1,920	.162
August	770	420	543	.0458
September	519	351	419	.0345
October	760	348	501	.0423
November	438	167	289	.0244
December	204	93	164	.014
1915				
January	135	89	104	.0088
February	90	64	72	.0061
March	445	64	150	.0127
April	2,355	290	1,330	.1123
May	635	435	498	.0420
June	1,585	500	947	.0799
July	2,785	1,360	1,962	.1656
August	2,295	1,225	1,788	.1509
September	1,180	515	707	.0597
October	520	425	459	.0387
November	450	139	225	.0190
December	150	71	102	.0086

NOTE.—Shifting conditions from June 24 to Sept. 6, 1912.

Sturgeon River

The Sturgeon river rises in Isle lake, about 50 miles due west of St. Albert, Alta. Isle lake is about eight miles in length and one mile in width, and drains approximately 80 square miles. Except near the outlet, the banks generally slope up to a height of from 50 to 100 feet above water-level, the country beyond being fairly level but rolling. At the outlet the surrounding country is low and marshy. The river channel is narrow and blocked with weeds, and the current is very sluggish.

Leaving Isle lake the Sturgeon river flows for about four miles through low, marshy lands, and empties into lake St. Ann. This lake is approximately 12 miles long, with an average width of about 2 miles. The Sturgeon flows out of the eastern end of the lake and continues in a general easterly direction to St. Albert, a distance of about 35 miles. Along its course the land is low, and swampy in many places.

At St. Albert the river enters Big lake, which is about seven miles long and one mile wide. The shores are low and swampy but the land beyond rises to an elevation of 100 feet or more above the lake. From the east end of Big lake, the river flows for about 30 miles in a north-easterly direction. Along this part the banks become steeper, the river in places flowing in a valley 100 feet deep and about 600 feet wide. At Battenburg the stream takes a sharp turn and flows in a south-easterly direction, a distance of about 10 miles, to the North Saskatchewan river.

Along the whole course of the Sturgeon river the predominating timber is poplar and balm of Gilead. Spruce occurs but not in abundance.

The municipality of Fort Saskatchewan built a hydro-electric plant on this river situated six miles from the town. The plant consisted of a 250-h.p. unit, and the electrical energy was transmitted at 6,600 volts, over a transmission line six miles in length, to a sub-station, where the voltage was stepped down to 2,200 volts through two 75-k.w. transformers. In 1912 the plant was undermined and destroyed and has not been rebuilt.

Gauging stations have been established on this river by the Irrigation branch of the Department of the Interior. The following are summaries of monthly discharges at St. Albert for 1913, and near Fort Saskatchewan for 1914 and 1915:

MONTHLY DISCHARGE OF THE STURGEON RIVER, AT ST. ALBERT

(Drainage area, 920 square miles.)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1913				
April (23-30)	579	460	516	.561
May	447	224	304	.330
June	137	106	114	.124
July	242	134	174	.189
August (1-9)	246	228	239	.260
September (3-30)	215	143	175	.190
October	142	108	122	.133
November	107	80	103	.112
December	67	28	53	.058

MONTHLY DISCHARGE OF THE STURGEON RIVER, NEAR FORT SASKATCHEWAN

(Drainage area, 1,330 square miles.)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1914				
January	46	16	27	.020
February	38	16	24	.018
March	49	32	38	.029
April	380	51	180	.135
May	218	86	132	.099
June	1,827	86	1,102	.828
July	1,450	480	915	.688
August	432	123	211	.159
September	123	106	117	.088
October	145	123	139	.104
November	200	76	121	.091
December	84	52	169	.052
1915				
January	61	55	58	.044
February	61	54	58	.044
March	450	55	90	.068
April	873	180	531	.399
May	240	108	156	.117
June	1,075	108	697	.524
July	921	410	663	.499
August	410	138	216	.162
September	138	110	117	.088
October	138	138	138	.104
November	219	114	150	.113
December	116	67	87	.065

Brazeau River

The Brazeau river, one of the chief tributaries of the North Saskatchewan, is a swift stream, rising in Brazeau lake, in the heart of the Rocky mountains, near the sources of the North Saskatchewan and Athabaska rivers. It flows north-easterly about 50 miles, and thence in a general easterly direction to its junction with the North Saskatchewan. Its principal tributaries in the mountain section are Job creek and Southesk river; in the foothill, the North and South branches and Nordegg river are the chief tributaries. The flow of the river, like all mountain streams, is greatly reduced in winter with floods in summer.

Several miles above Job creek the river flows through a limestone cañon about three-quarters of a mile in length, from 100 to 150 feet deep, and varying in width from 50 to 150 feet. Toward the lower end of this cañon a series of falls have a total descent of 45 feet in a distance of approximately 200 feet. With the exception of this cañon,

the banks of the river, from a point about two miles below Brazeau lake down to near the mouth of the Southesk river, are low, sloping up to the base of the mountains which form the sides of the valley as far as Southesk river. For a short distance above Southesk river, both banks are high. About 300 feet below the Southesk, the Brazeau cuts through a sandstone dyke in a short cañon about 300 feet long; the right bank is 80 feet and the left 110 feet high. For a distance of approximately 1,000 feet below the cañon, both banks are high and precipitous. From this point down to Thistle creek, banks are alternately high and low, the tortuous stream being broken by series of small cascades. Below Thistle creek, the fall of the river is less rapid, the current gradually diminishing to the junction with the North Saskatchewan.

Above the Southesk, the drainage basin is covered with a growth of small jackpine and spruce, with occasional clumps of large spruce. Below the Southesk the surrounding country is thickly strewn with fallen timber and covered with a dense growth of small jackpine.

The following discharges have been observed on the Brazeau river:

DISCHARGE OF THE BRAZEAU RIVER

Date	Location	Discharge in second-feet
1913		
July 9	39-21-5	702
July 11	39-21-5	751
July 13	39-21-5	802
July 15	Outlet of Brazeau lake	208*
1914		
February 3	At junction with North Saskatchewan	222
March 18	At junction with North Saskatchewan	285
March 19	At junction with North Saskatchewan	283
Oct. 15	½ m. below Brazeau lake	109

* May not represent total flow at this point.

Clearwater River

The Clearwater, one of the mountain tributaries of the North Saskatchewan river, rises in one of the inner ranges of the Rocky mountains. Its source is near the headwaters of Pipestone creek, which flows south-westward into the Bow river, while the Clearwater river takes a north-easterly course. The latter leaves the mountains in lat. 51° 57′, long. 115° 42′, and eventually empties into the North Saskatchewan near Rocky Mountain House. Through the foothills, and as far east as the main pack-trail, north from Morley, the

banks of the river are reported to be heavily wooded. At the trail crossing the south bank is steep and well-timbered with spruce and poplar; the northern recedes for nearly a mile as a wide, grassy flat, with small pines and poplars scattered over it.

The Clearwater, at its mouth, is a swift, clear stream, 150 feet wide and from fifteen inches to two feet in depth, flowing over a bed of rounded, quartzite pebbles. Higher upstream, the channel is divided in many places by wide gravel bars, which are submerged during high water.

A gauging station was established on this river near Rocky Mountain House by the Irrigation branch. The following is a summary of discharges at this station for 1914 and 1915:

MONTHLY DISCHARGE OF THE CLEARWATER RIVER, NEAR ROCKY MOUNTAIN HOUSE

(Drainage area, 850 square miles.)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1914				
January	240	128	190	.224
February	225	160	197	.232
March	270	150	232	.273
April	458	240	449	.528
May	1,196	324	746	.878
June	2,280	354	1,376	1.620
July	1,915	834	1,406	1.650
August	1,025	610	783	.921
September	834	465	610	.718
October	850	395	603	.709
November	535	280	426	.501
December	269	125	185	.218
1915				
January	206	160	175	.199
February	212	183	194	.220
March	302	188	248	.282
April	450	295	359	.407
May	2,488	480	1,618	1.84
June	39,100	2,164	5,688	6.46
July	12,540	3,208	5,881	6.68
August	10,024	2,126	3,180	3.61
September	2,238	1,230	1,590	1.80
October	1,340	845	1,023	1.16
November	952	621	766	.869
December	607	305	460	.522

CHAPTER VIII

South Saskatchewan River and Tributaries except Bow River

The South Saskatchewan rises in the mountains of south-western Alberta. Between the Bow river and Cherry coulée, high, scarped, barren banks rise on both sides of the river, and the general level of the prairie is nearly 250 feet above the water at the latter point. The width of the stream is approximately 1,000 feet. The river is tranquil as far as Medicine Hat, but the valley is narrow, and, in places, cañon-like, with banks from 250 to 300 feet in height. Its direction in this upper part is east, although at Medicine Hat the course changes somewhat abruptly. In this distance of 100 miles the descent is nearly two feet per mile, and the current, in time of low water, flows at the average rate of two and three-quarter miles per hour, approximately.

For 12 or 15 miles below Medicine Hat, the river follows a rather tortuous course, through large clay-flats usually wooded with groves of cottonwood. The next section, extending as far as Drowning Man ford, is much straighter, while the bordering flats are very narrow. To the east of Drowning Man ford, the river enters higher ground; the valley landscape, hitherto somewhat monotonous, assumes a much more striking character. The sloping, grassy banks, which characterize it farther up, are replaced by high, precipitous cliffs of bare, gray rock, while the valley narrows until in many places its breadth scarcely exceeds that of the stream. The height of the plateau above the river is nearly 500 feet. The cañon-like appearance of the valley prevails for over 30 miles, after which the Cretaceous rocks, by which the river-valley has been confined, gradually sink beneath the softer, Post-Tertiary deposits. Between the eastern end of the cañon and the mouth of the Red Deer river, the valley is about one mile and a half wide and 400 feet in depth. Its banks, except near the bends of the river, are grassy, and it contains occasional wide bottoms, some of which support large groves, principally of cottonwood. Below the mouth of the Red Deer, the valley is approximately 200 feet deep.

Below Mouth of Red Deer

The valley of the South Saskatchewan, east of the mouth of the Red Deer, is of very uniform character for many miles. It is, as a rule, wide, and contains extensive and valuable bottoms, which, especially in the upper part of this section, are often well wooded. The grassy banks slope gently upward to the prairie level; scarped banks are of rare occurrence.

The total distance from the mouth of the Red Deer river to the "Elbow," measured in three-mile stretches, is about 180 miles. The elevation of the former point is 1,901 feet, and of the latter 1,660 feet; this gives the river an average descent of 1·3 feet per mile. The fall is very evenly distributed and rapids are few but the great number of shifting sand-bars, which block the channel for nearly its entire length, makes navigation, except in time of high water, a matter of extreme difficulty. In some places the river is nearly a mile wide, and divides into several streams, separated by wide bars or sandy islands, through which it is difficult for even a small boat to find a passage.

A power site has been surveyed at a point 15 miles below Saskatoon, where a head of 15 feet could be created by building a dam. The development project has been abandoned temporarily, probably on account of the excessive cost of construction. Gauging stations were established at Medicine Hat and Saskatoon by the Irrigation branch of the Department of the Interior in 1911. The following is a summary of discharges:

MONTHLY DISCHARGE OF SOUTH SASKATCHEWAN RIVER, AT MEDICINE HAT

(Drainage area, 20,870 square miles.)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1911				
June	40,140	14,250	32,694	1.57
July	33,575	13,500	25,825	1.24
August (1-26)	25,500	13,500	18,545	0.89
November	7,790	4,360	4,228	0.20
December	4,562	790	2,501	0.12
1912				
January	2,166	1,016	1,663	0.08
February	2,504	1,776	2,134	0.10
March (1-24 and 27)	2,940	1,550	1,792	0.09
April (10-19)	7,772	6,252	6,746	0.32
May (3-31)	20,020	6,056	12,887	0.62
June	39,815	9,905	19,121	0.92
July	30,715	18,080	21,513	1.03
August	18,620	10,090	13,292	0.64
September	13,050	6,560	8,698	0.42
October	6,364	5,760	6,065	0.29
November	5,904	3,000	5,099	0.24
December	3,040	2,056	2,376	0.11

MONTHLY DISCHARGE OF SOUTH SASKATCHEWAN RIVER, AT MEDICINE HAT.—*Continued*

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1913				
January	2,370	975	1,652	0.079
February	2,370	1,640	2,013	0.096
March	2,550	1,660	2,059	0.099
April	15,960	2,300	8,977	0.425
May	32,273	6,422	12,412	0.595
June	34,415	23,195	29,747	1.42
July	31,160	10,294	16,907	0.810
August	19,931	8,680	12,260	0.587
September	10,442	5,326	7,592	0.364
October	8,090	5,115	5,873	0.281
November	5,470	2,242	4,647	0.223
December	4,070	1,920	3,117	0.149
1914				
January	3,580	1,480	2,547	0.122
February	1,810	1,310	1,577	0.075
March	6,184	1,860	4,022	0.193
April	9,185	2,730	5,754	0.275
May	20,350	6,800	14,679	0.703
June	25,500	13,450	19,831	0.950
July	19,600	7,220	14,122	0.677
August	7,700	5,100	6,590	0.315
September	5,625	2,420	4,486	0.215
October	12,725	4,775	7,600	0.364
November	6,860	4,100	5,556	0.266
December	4,300	1,120	1,873	0.090
1915				
January	2,860	1,720	2,305	.110
February	2,030	1,890	1,982	.095
March	16,650	1,820	6,176	.296
April	7,830	3,470	5,345	.256
May	32,100	5,814	19,354	.927
June	84,700	20,162	32,275	1.547
July	47,896	23,164	32,997	1.581
August	33,205	10,652	18,470	.880
September	11,212	6,822	8,815	.422
October	8,640	5,656	7,112	.341
November	7,830	3,140	4,537	.217
December	3,140	1,660	2,378	.114

MONTHLY DISCHARGE OF SOUTH SASKATCHEWAN RIVER, AT SASKATOON

Month	Discharge in second-feet		
	Maximum	Minimum	Mean
1911			
May (28-31)	24,600	19,350	22,688
June	43,100	18,250	32,477
July	46,600	19,350	27,684
August	43,800	16,600	23,503
September	35,400	11,950	20,357
October (1-19)	13,400	3,000	8,476
November (20-30)	3,550	1,888	2,434
December	5,450	2,025	3,945

MONTHLY DISCHARGE OF SOUTH SASKATCHEWAN RIVER, AT SASKATOON.—*Continued*

Month	Discharge in second-feet		
	Maximum	Minimum	Mean
1912			
January	2,325	1,350	1,686
February	2,525	2,112	2,297
March	2,525	2,000	2,304
April	37,300	2,330	14,152
May	25,000	8,355	14,737
June	44,790	12,850	23,204
July	50,320	23,380	33,602
August	43,320	15,950	23,681
September	21,550	10,680	16,359
October	10,400	8,530	9,293
November	9,755	4,140	7,414
1913			
January	1,425	1,130	1,247
February	2,390	1,310	1,981
March	2,520	2,370	2,432
April	37,950	2,550	15,852
May	19,850	7,260	11,937
June	38,230	17,025	32,436
July	42,710	13,690	24,232
August	19,500	11,670	14,854
September	11,635	6,960	9,143
October	8,880	6,630	7,909
November	12,160	5,080	6,079
December	4,950	2,150	3,752
1914			
January	3,250	2,320	2,702
February	2,370	1,860	2,130
March	3,630	2,200	3,038
April	9,020	3,620	6,319
May	23,370	7,500	13,876
June	35,128	16,585	26.375
July	28,752	14,630	22,694
August	14,160	8,380	9,762
September	9,550	7,020	7,945
October	16,382	7,077	10,315
November	13,350	5,300	8,151
December	7,210	1,570	3,482
1915			
January	4,100	2,500	3,379
February	2,750	2,150	2,345
March	5,800	2,700	3,318
April	43,880	6,650	13,472
May	34,790	7,375	19,813
June	48,170	26,505	36,144
July	111,012	36,390	60,566
August	56,645	20,060	33,704
September	26,355	12,310	16.357
October	14,620	10,025	12,714
November	9,820	4,200	6,118
December	4,800	2,550	3,855

NOTE.—As this stream is fed mainly from the mountains, it was decided not to give the discharge per square mile of the area. Such figures would give an erroneous idea of the run-off as the mountains form only a small part of the whole basin.

Swift Current Creek

Swift Current creek rises on the eastern slope of the Cypress hills and flows north-easterly for 75 miles, thence northerly for about 25 miles to the South Saskatchewan. It flows through a valley, 200 to 300 feet deep and a mile wide, to within a few miles of its mouth, where it enters a sandstone gorge, about five hundred feet deep. The bench land above the creek is of rolling prairie, broken by innumerable coulées. The soil is a sandy loam. The tree growth along the stream is sparse.

The mean annual rainfall at the town of Swift Current is about fifteen inches. This increases slightly at the stream's headwaters. The greatest precipitation occurs during the months of May, June, and July. From November to April the stream is frozen over.

There are a number of small irrigation ditches in this drainage basin, and the town of Swift Current and the Canadian Pacific railway take water for domestic and industrial purposes from the creek.

The following are summaries of discharges at two of the gauging stations established by the Irrigation branch:

MONTHLY DISCHARGE OF SWIFT CURRENT CREEK, AT SINCLAIR'S RANCH, LOWER STATION

(Sec. 17, Tp. 10, Rge. XIX, W. 3 M.) (Drainage area, 366 square miles.)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1910				
May (27-31)	15.5	14.30	14.940	.041
June	23.16	6.92	14.316	.039
July	14.1	2.82	7.223	.020
August	10.9	2.12	7.186	.020
September	17.0	8.72	12.738	.035
October	15.1	12.70	13.790	.038
1911				
May (12-31)	54	24	37.9	.104
June	45	6.6	21.9	.060
July	42	4.3	17	.047
August	39	4	12.2	.033
September	101	5.3	30	.082
October	44	17	25.6	.07
1912				
May (16-31)	134	51	80	.218
June	147	8.5	39.4	.108
July	38	8.5	16.9	.046
August	12.3	7.1	10.2	.028
September	17.1	10.9	15.1	.041
October	32	15.2	23.6	.064
November (1-15)	38	28	33.7	.092

MONTHLY DISCHARGE OF SWIFT CURRENT CREEK, AT SINCLAIR'S RANCH, LOWER STATION.—*Continued*

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1913				
April (22-30)	234.0	32.0	40.3	.110
May	41.0	20.0	30.7	.083
June	45.0	10.0	21.9	.060
July	22.0	4.8	11.7	.032
August	7.5	3.6	5.1	.014
September	19.1	4.1	8.0	.022
October	22.0	8.6	13.1	.036
1914				
April	210.0	30.00	102.00	.280
May	37.0	12.80	22.00	.060
June	45.0	8.80	1.86	.050
July	11.9	.40	2.90	.008
August	4.9	Nil	1.08	.003
September	64.0	2.70	14.10	.038
October	94.0	7.60	33.00	.091
1915				
March (28-31)	418	273	350	.956
April	215	28	83	.227
May	276	24	52	.143
June	139	32	64	.175
July	290	17	44	.120
August	16	7	9	.026
September	26	7	16	.043
October	43	15	28	.076

MONTHLY DISCHARGE OF SWIFT CURRENT CREEK, AT SWIFT CURRENT, SASK.

(Drainage area, 1,015 square miles)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1910				
May	76	28	37.5	.037
June	36	12	21.4	.021
July	36	0	15.0	.015
August	23	0	8.55	.008
September	33	8	18.2	.018
October	34	11	14.5	.014
1911				
March (27-31)	600	365	498	.491
April	896	136	427	.421
May	117	58	76.1	.075
June	79	7	40	.039
July	62	3	27.8	.027
August	34	3	16.7	.016
September	137	14	48.9	.048
October	46	17	31.9	.031

MONTHLY DISCHARGE OF SWIFT CURRENT CREEK, AT SWIFT CURRENT, SASK.—*Continued*

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1912				
April (21-30)	308	226	255	.251
May	169	90	136.4	.134
June	169	26	91.3	.09
July	39	23	26.7	.026
August	30	22	24.3	.024
September	36	27	29.6	.029
October	119	33	42.9	.042
November*	85	14.7	32.6	.032
December*	22.9	9.7	11.4	.011
1913				
April (9-30)	607.0	35.0	193.00	.190
May	78.0	39.0	55.40	.055
June	92.0	24.0	45.20	.045
July	68.0	7.8	34.20	.034
August	16.8	5.6	10.50	.010
September	21.0	2.2	4.73	.005
October	26.0	12.6	18.80	.019
1914				
January	2.6	1.05	1.77	.0018
February	2.6	1.20	2.07	.0020
March	344.0	4.00	102.00	.1020
April	386.0	55.00	228.00	.2280
May	71.0	17.20	41.00	.0410
June	179.0	2.40	29.00	.0290
July	15.2	2.40	6.50	.0065
August	4.4	.10	.73	.0007
September	89.0	.13	20.00	.0200
October	89.0	12.30	35.00	.0350
November	36.0	12.00	21.00	.0210
December	36.0	5.30	10.80	.0110
1915				
January	9	3	5	.005
February	3	3	3	.003
March	670	3	118	.118
April	988	61	231	.231
May	137	49	72	.072
June	159	35	73	.073
July	188	59	85	.085
August	63	8	26	.026
September	27	11	21	.021
October	40	20	31	.031
November	31	4	22	.022
December	18	8	11	.011

* Figures during ice conditions (Nov. 15 to Dec. 31) are only estimates.

Red Deer River

The Red Deer river rises in one of the interior ranges of the Rocky mountains, in lat. 51° 30′, long. 116° W., near a branch of Pipestone creek, which flows southward into Bow river. It leaves the mountains in lat. 51° 43′, long. 115° 23′ W., and flows easterly through the foothills, reaching the crossing of the Stoney pack-trail,

slightly to the east of long. 115° W. Here it is a stream of clear, blue water, 200 feet wide and two feet deep, flowing over a bed of quartzite pebbles and boulders. Immediately below the ford, it turns sharply to the north, following the west side of a high, sandstone ridge, and is bordered on the west by a strip of bench land, one-half mile wide, and partly covered with fallen timber.

Near the mouth of Raven river it turns eastward; thence to the mouth of Little Red Deer, the river is winding and very swift. It is bordered alternately by scarped, sandstone banks and wide, gravel flats, in some cases open and grassy, in others heavily timbered with large spruce. The descent in this distance is approximately 200 feet, or 15 feet per mile.

From the mouth of the Little Red Deer, the Red Deer flows east for one mile and a half, when it is joined from the north by the Medicine river. One of the roughest rapids occurs in this portion of its course.

Below the mouth of Medicine river, it becomes much deeper and has a steadier current, with few rapids.

From the town of Red Deer to the mouth of Blindman river, a distance, by water, of eight and one-half miles, the river is very tortuous. The banks are 150 feet in height, abrupt and scarped on the outer sides of the bends, but, on the opposite sides, receding from the edge of the stream to fine, alluvial flats, partly wooded with an irregular growth of poplar and willow.

Power Possibilities

Three power-sites have been investigated in the vicinity of the town of Red Deer. Although this section of the river has no concentrated descents, other natural conditions aid power development, either by diverting or by damming the river to create a head. The first of these sites is opposite the town, where a head of 15 feet could be obtained. The second site is situated eight miles below the town, measured along the river, but only six miles in a straight line; here a head of 25 feet could be obtained by diversion across one of the long bends of the river. The third site is 13 miles below the town, following the river, but only seven miles in a straight line. The river could be dammed at this point, creating a head of 25 feet.

An examination by the Water Power branch demonstrated the possibility of combining the second and third sites, thus obtaining a head of 100 feet. Owing to the low winter flow, however, it is not economically feasible.

A fourth site, some three or four miles above the town, is not considered feasible of development.

At the mouth of the Blindman, the Red Deer turns abruptly and flows southeast for 14 miles. It cuts through the high ridge to the

NORWAY HOUSE, ON NELSON RIVER

HAYES RIVER—RAPID, SIX MILES BELOW ROBINSON LAKE

east of Red Deer in what is locally known as the "Cañon," in which the banks are high and steep, though not always scarped. Below the "Cañon" the valley expands; grassy slopes extend to the water's edge on the north side but the south side continues thickly wooded. From the end of this stretch, the river flows eastward for six miles between low and sloping banks.

From Red Deer to Tail creek, the outlet of Buffalo lake, the river has a strong current, with numerous short rapids, and an average descent of 5½ feet per mile.

From the mouth of Tail creek to the mouth of Rosebud river, the Red Deer has an average descent of 3 feet per mile, exclusive of its minor flexures. It has a current of two and a quarter miles per hour and a mean depth of three feet; the channel is so obstructed by constantly shifting sand-bars that it cannot be considered in any sense navigable.

The valley of the Red Deer is wide and deep, while the banks are rough and broken by numerous deep coulées draining into the river. Near the source the basin is well-timbered, and a fair growth of timber is found along its banks for some distance through the prairie.

A gauging station was established at Red Deer in the month of December, 1911, by the Irrigation branch. Two discharge measurements were taken in that month. One, on the 2nd, gave 638 second-feet, and another, on the 14th and 15th, 545 second-feet. The following are the subsequent observations at this station:

MONTHLY DISCHARGE OF RED DEER RIVER, AT RED DEER, ALTA.
(Drainage area, 4,500 square miles)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1912				
January	264	222	238	.053
February	313	248	274	.061
March (1-28)	1,425	246	401	.089
April	2,698	1,290	1,919	.427
May	7,040	1,705	3,954	.879
June	13,532	1,450	3,953	.879
July	19,043	3,232	10,091	2.24
August	7,010	3,340	4,985	1.111
September	8,744	2,908	4,532	1.005
October	4,353	1,585	2,721	.605
November	1,765	560	1,290	.287
December	867	434	545	.121
1913				
January	436	373	417	.093
February	431	360	396	.088
March	440	370	410	.091
April	10,236	460	3,887	.864
May	9,477	1,262	4,101	.912
June	13,500	2,648	4,946	1.097
July	11,960	3,251	5,242	1.164

MONTHLY DISCHARGE OF RED DEER RIVER, AT RED DEER, ALTA
Continued

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1913—*Con.*				
August	5,482	2,153	3,284	.730
September	2,944	1,280	1,787	.397
October	1,441	900	1,223	.272
November	1,080	585	825	.183
December	555	105	327	.073
1914				
January	309	195	278	.062
February	330	270	298	.066
March	425	338	380	.084
April	2,266	390	902	.200
May	2,815	1,110	1,908	.424
June	5,559	1,300	3,669	.815
July	3,294	1,424	2,351	.522
August	1,544	1,120	1,309	.291
September	1,350	996	1,098	.244
October	2,698	1,005	1,439	.320
November	996	715	783	.174
December	690	200	328	.073
1915				
January	330	240	278	.062
February	280	260	271	.060
March	1,560	285	606	.135
April	1,870	920	1,251	.278
May	7,040	1,175	4,457	.990
June	56,000	4,692	12,308	2.740
July	46,200	6,072	16,748	3.720
August	30,775	4,490	8,118	1.800
September	5,116	3,266	3,954	.879
October	4,243	2,208	2,934	.652
November	2,222	565	1,195	.266
December	615	465	520	.116

Blindman River

The Blindman river rises in the foothills, about 50 miles northwest of the town of Red Deer. Below the confluence of the East and West branches, it flows in the same valley for two miles and a half, and then, although the valley continues, the stream leaves it and, cutting a narrow gorge through the high ridge to the west, enters another valley. Thence to the mouth of Gull creek, it flows in a winding channel, 40 feet in width and from 10 to 20 feet below the level of the flat. Gull creek carries the discharge of Gull lake, a body of clear water, 11 miles long and four miles wide, situated only three miles to the east of the main stream. Below Gull creek the river flows almost due south, for a distance of four miles, in a channel from 20 to 30 feet deep. The valley is marked only by wide slopes stretching toward the east and the west. The river then turns eastward, and flows for 14 miles through a deep, narrow valley; it joins the Red Deer a few miles below the town of Red Deer.

The following discharges of this river have been recorded by the Irrigation branch of the Department of the Interior:

DISCHARGES OF THE BLINDMAN RIVER, AT BLACKFALDS, ALTA.

Date	Discharge in second-feet	Date	Discharge in second-feet
1913		1914	
April 16	860	August 24	41.0
May 8	113	September 17	95.0
May 27	116	September 26	68.0
June 17	325	October 17	94.0
July 9	247	November 7	25.0
July 17	1,374	December 5	24.0
July 28	102	1915	
August 8	70	February 6	11.04
August 20	408	February 27	9.1
September 6	102	March 20	135
September 26	71	April 17	122
October 14	67	May 5	178
December 17	17	May 22	96
December 29	10	June 8	697
1914		July 12	758
January 7	12.1	August 14	102
January 21	13.8	September 1	88
February 25	22.0	September 21	148
March 4	24.0	October 12	141
April 24	178.0	October 23	123
July 15	166.0	December 4	30
August 14	59.0	December 30	32

Hydro-Electric Development

The town of Lacombe has constructed a hydro-electric plant near the mouth of this river. The installation consists of a 35-inch turbine, operating under a head of 30 feet and driving a 150-k.w. generator. The electrical energy is generated at 6,600 volts, three phase, 60 cycles, and is transmitted eight miles over a three-conductor transmission line, to Lacombe. The sub-station equipment consists of three 30-k.w. transformers, stepping the voltage down from 6,600 to 2,300 volts. It is stated that the flow of the river is very irregular, and becomes insufficient to operate the plant between the months of October and March. To conserve the water, a small dam was built at the outlet of Gull lake but, owing to the nature of the outlet and to the attitude of the farmers with respect to its control, very little, if any, benefit is derived therefrom. The town has also an auxiliary steam-plant of 60-k.w. capacity. It is the intention of the municipality to build a new power dam and to increase the capacity of the steam auxiliary plant by 100 k.w.

Oldman River

Oldman river, one of the principal tributaries of the South Saskatchewan* river, is formed by the union of numerous small streams which

*By a recent decision of the Geographic Board, the name Oldman is applied to the main stream from the confluence with the Belly, downstream to its junction with the Bow.

originate in the mountains. The more important of these are the Livingstone, Dutch creek, Racehorse creek, Crowsnest, Southfork, Belly, St. Mary and Little Bow rivers. It drains an area of approximately 9,424 square miles, varying in character from mountainous districts to rolling prairie.

'The Gap,' situated near the mouth of Racehorse creek, is a narrow, rugged gorge crossing the Livingstone range. Its course follows a double curve, somewhat in the shape of the letter **S**, and is one mile and a half in length. The flow is very rapid in this part of the course, but shows no abrupt descent.

The section of the foothill belt through which the upper branches of the Oldman river flow is densely wooded along the base of the mountains and contains occasional prairie valleys. The bed of the river, consisting of rock and gravel, has a steep descent, with consequent swift water, interspersed with falls and rapids, but it changes to quicksand and mud in the prairie region where the current is more sluggish.

Between the mouth of the Livingstone and the Gap, a distance of 16 miles, the Oldman descends about 900 feet; between the mouth of Dutch creek and the Gap, a distance of five miles, the descent is approximately 212 feet. Below the Gap the descent continues fairly steep; in the 35 miles from this point to the mouth of the Crowsnest river, the fall is about 800 feet. Below the mouth of Pincher creek, the descent gradually becomes less marked. In the 29 miles between the mouth of Pincher creek and Macleod the fall is 285 feet, and thence to the junction with the Belly river, a distance of 24 miles, the river descends only 144 feet.

The Irrigation branch of the Department of the Interior established gauging stations on this river near Cowley, in 1908, and at Lethbridge in 1911. The following is a summary of the discharges since that year:

MONTHLY DISCHARGE OF OLDMAN RIVER, NEAR COWLEY, ALTA.

(Drainage area, 820 square miles.)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1908				
June (17-30)	2,990	1,500	2,167	2.64
July	1,500	460	956	1.17
August	460	225	311	0.38
September	225	170	186	0.23
October	225	170	181	0.22

MONTHLY DISCHARGE OF OLDMAN RIVER, NEAR COWLEY, ALTA.
—*Continued*

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1909				
May	4,690	265	1,433	1.75
June	8,285	1,525	3,386	4.13
July (1-24)	2,020	662	1,381	1.68
August	1,680	310	682	0.83
September	310	200	252	0.31
October	200	175	178	0.22
1910				
May (18-31)	1,760	980	1,250	1.52
June	1,058	546	826	1.01
July	548	199	323	0.39
August	199	174	191	0.23
September	296	174	213	0.26
October	756	238	324	0.39
November (1-28)	345	242	274	0.33
1911				
January	112	66	97.2	0.118
February	143	69	117	0.143
March	184	66	110	0.134
April	1,139	134	369	0.45
May	5,580	533	1,262	1.54
June	4,350	978	2,052	2.50
July	1,014	337	565	0.689
August	2,319	390	809	0.987
September	2,970	390	996	1.21
October	496	300	371	0.452
November	461	174	266	0.325
December	205	98	182	0.222
1912				
January	90	77	84.4	0.103
February	92	78	85.4	0.104
March (1-15)	92	85	87.6	0.107
April	2,020	270	540.0	0.658
May	1,238	360	826	1.01
June	7,140	672	3,058	3.73
July	2,290	727	1,079	1.32
August	1,238	337	557	0.679
September	270	229	253	0.308
October	256	203	223	0.272
November	229	145	204	0.249
December	170	145	147	0.179
1913				
January	145	97	112	0.136
February	124	106	116	0.141
March	126	74	104	0.127
April	1,490	130	714	0.871
May	2,381	465	1,709	2.080
June	2,245	1,074	1,720	2.100

MONTHLY DISCHARGE OF OLDMAN RIVER, NEAR COWLEY, ALTA.
—*Continued*

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1913—*Con.*				
July	1,446	458	601	0.733
August	1,074	331	548	0.668
September	450	255	333	0.406
October	316	245	283	0.345
November	297	180	255	0.311
December	185	160	176	0.214
1914				
January	160	86	122	.15
February	98	85	90	.11
March	142	84	97	.12
April	695	133	372	.45
May	1,960	455	1,346	1.64
June	2,016	840	1,275	1.55
July	1,005	290	605	.74
August	490	205	270	.33
September	290	164	202	.25
October	1,038	200	449	.55
November	448	254	375	.46
December	280	127	155	.19
1915				
January	203	101	172	.215
February	147	53	106	.132
March	191	52	105	.131
April	855	207	494	.618
May	2,992	1,379	2,306	2.882
June	4,350	1,365	2,450	3.100
July	2,658	756	1,341	1.676
August	1,407	426	693	.866
September	499	360	401	.501
October	485	365	407	.509
November	464	180	322	.402
December	196	110	149	.186

MONTHLY DISCHARGE OF OLDMAN RIVER, NEAR LETHBRIDGE, ALTA.

(Drainage area, 6,764 square miles.)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1911				
September	22,050	2,125	8,788	1.30
October	4,350	1,912	2,836	.42
November	2,500	1,712	2,135	.32
December	1,912	1,412	1,672	.25
1912				
January	990	930	964	.14
February	987	753	896	.13
March	6,554	708	1,806	.27
April	4,890	2,250	3,610	.54
May	12,970	5,602	7,886	1.17
June	14,810	6,375	7,883	1.17

MONTHLY DISCHARGE OF OLDMAN RIVER, NEAR LETHBRIDGE, ALTA.—*Continued*

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1912—*Con.*				
July	8,110	4,910	6,792	1.01
August	5,010	1,675	2,953	.44
September	1,898	1,430	1,625	.24
October	2,018	1,322	1,636	.24
November (1-27)	2,280	1,367	1,856	.27
1913				
January	860	460	618	.09
February	460	380	412	.06
March	600	418	451	.07
April	8,450	800	5,114	.76
May	24,940	4,405	9,384	1.39
June	23,090	9,736	15,795	2.33
July	12,920	3,760	6,087	.90
August	5,783	2,325	3,487	.52
September	2,618	1,383	1,952	.29
October	2,744	1,383	2,121	.31
November	2,188	1,230	1,786	.26
December	1,428	300	904	.13
1914				
January	740	602	671	.099
February	840	560	622	.092
March	1,484	290	1,122	.166
April	5,691	1,460	3,412	.505
May	11,680	4,880	8,606	1.270
June	12,324	5,592	7,928	1.170
July	5,795	1,824	3,799	.562
August	3,112	1,120	1,923	.284
September	2,482	1,219	1,616	.239
October	7,935	1,788	3,999	.591
November	3,896	1,680	2,995	.443
December	2,040	704	1,094	.162
1915				
January	1,283	645	916	.135
February	766	690	722	.107
March	6,160	642	1,962	.290
April	5,401	1,730	3,475	.514
May	14,798	4,280	10,500	1.552
June	22,100	8,990	14,438	2.135
July	15,680	5,907	9,165	1.355
August	8,672	2,824	5,107	.755
September	4,778	2,712	3,316	.490
October	4,240	2,880	3,591	.531
November	3,158	1,080	2,095	.310
December	1,073	876	984	.145

St. Mary River

The upper valley of the St. Mary river is well defined. It is one-half mile wide, consisting of rolling slopes (open prairie with no timber); the river cuts through it at an average depth of 140 feet. The water is cold and free from silt. From the southeast quarter of section 23 to the northwest corner of section 25, township 1, range

XXX, the river flows through a cañon, 150 feet in depth. The bottom is of solid sandstone, visible nearly everywhere. The banks consist of layers of sandstone and hard clay. In the upper portion of the river valley, as far as the international boundary, there are, alternately, flats and cut-banks 50 to 100 feet high.

The Alberta Railway and Irrigation Co. has water rights on this river. The head-gates of its canal are at Kimball, five miles north of the international boundary, and the company already has hundreds of miles of ditch constructed for the irrigation of land surrounding Lethbridge.

Power Sites Available

There is a possible power-site on the upper St. Mary at section 23, township 1, range XXV, where a head could be created by a dam 140 feet high. It is stated, however, that an effective head of 238 feet and a more economical development could be obtained by diversion, from a point near the boundary line, through a canal and pipe line to a point situated above the intake of the Alberta Railway and Irrigation Company, a distance of seven miles.

However, the above scheme may not be feasible, as, in the general scheme for irrigation in Southern Alberta, the Irrigation branch contemplates the construction of a dam on the St. Mary river to divert the peak of the summer flood to the Mary lakes. The proposed dam is to be built in section 9, township 1, range XXV, west 4th meridian, and will be 105 feet high. In the event of the flow being regulated to suit the irrigation interests, a regulated flow of 1,000 c.f.s. would be available for seven months. For the remaining five months 100 c.f.s. is about the maximum flow that could be depended upon, since, while the average minimum flow of the St. Mary river is 200 c.f.s., the irrigation interests would, in all probability, exercise their right to one-half of the flow of the stream and store 100 c.f.s. With 1,000 c.f.s. and 105 foot head it is possible to develop 9,500 h.p. for seven months, and, for the remaining five months, with 100 c.f.s., 950 h.p. could be developed. As the water in this case is chiefly used for irrigation, and as its control is subject to the International Joint Commission, special power regulations are practically impossible.

The Boundary Waters treaty, 1910, provided that the St. Mary and Milk rivers and their tributaries in Montana, Alberta and Saskatchewan "are to be treated as one stream for the purposes of irrigation and power and the waters thereof shall be apportioned equally" between Canada and the United States. This provision was inserted to protect the citizens of the two countries who depend upon irrigation to produce crops. The two streams are treated as one inasmuch as the United States has diverted part of the waters of the St. Mary to

the Milk river, thus permitting the irrigation of large areas in its portion of the Milk River basin.

Canadian interests offered the below suggestion for apportionment of the waters of the St. Mary and Milk rivers:

Canada		United States
Acre-feet		Acre-feet
500,290	St. Mary river up to a maximum flow of 2,000 second-feet, May to October, inclusive.........	
72,000†	St. Mary river below A. R. & I. intake	
	St. Mary river from November to April, inclusive.	131,662
	St. Mary river—peaks of over 2,000 second-feet, flood flow in summer	103,500
	Milk river at Eastern Crossing	100,000
		335,162
	Less delivered at A. R. & I., intake on Milk river	76,400
	Equals	258,762*†
20,000*	Milk river at A. R. & I. Co.'s intake—during floods	
76,400†	Milk river at A. R. & I. Co.'s intake—St. Mary or Milk river waters	
136,000	Northern tributaries of Milk river—stored or diverted by Canada.	
	Ditto passed by Canada	54,000
	Milk river and tributaries below Eastern Crossing up to Hinsdale or Vandalia	350,000
	Ditto below Vandalia	72,000†
804,690		734,762

On the lower St. Mary a good power site is available at section 24, township 6, range XXIII. The dam could be about 90 feet in height but very little water would be available during the irrigation season, as almost all of the flow is diverted for this purpose above this site.

A gauging station has been established on this river at Kimball, Alta., and discharge measurements taken by the Irrigation branch of the Department of the Interior. The station is above the intake of the Alberta Railway and Irrigation Company and measures the flow from a drainage area of 472 square miles. Records from this station are available only since 1909. Prior to 1909, the United States Geological Survey maintained a gauging station near Cardston, a short distance above Kimball, where the drainage area is 452 square miles. The following is a summary of discharges at these stations:

NOTE.—The difference between the total quantities is a low estimate of the value of the Canadian prior appropriation on St. Mary river as compared with the United States prior appropriation on the Milk river.

*Estimated capacity of A. R. and I. Co's. Milk River canal.

†These amounts are not at present considered available for irrigation but possibly for power.

*†Mr. Newell has stated that about 200,000 acre-feet will be required by the United States.

MONTHLY DISCHARGE OF ST. MARY RIVER, NEAR CARDSTON, ALTA.
(Drainage area, 452 square miles)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1907				
January*			150	0.332
February*			200	.443
March*			150	.332
April	685	225	489	1.08
May	3,490	590	1,930	4.27
June	5,620	3,260	4,260	9.42
July	4,830	2,010	3,120	6.90
August	2,010	830	1,330	2.94
September	1,330	1,080	1,210	2.68
October	1,040	365	567	1.25
November	365	174	244	.542
December*			157	.347
The year	5,620		1,150	2.54
1908				
January†			50	0.111
February†			100	.221
March†			225	.498
April	1,860	225	844	1.87
May	3,720	1,340	2,490	5.51
June	18,000	2,700	6,390	14.1
July	3,050	1,180	2,490	5.51
August	1,180	528	785	1.74
September	510	425	462	1.02
October	660	365	485	1.07
November	528	410	472	1.04
December†			125	.277
The year			1,240	2.75

* Ice conditions and discharge estimated January to March and December 15-31, 1907.

† Ice conditions and discharge estimated.

MONTHLY DISCHARGE OF ST. MARY RIVER, AT KIMBALL, ALTA.
(Drainage area, 472 square miles.)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1909				
April (26-30)	575	427	505	1.078
May	4,380	290	1,906	4.039
June	7,280	3,415	5,646	11.961
July	6,167	1,820	3,096	6.560
August	3,510	760	1,466	3.107
September	815	480	645	1.366
October	565	307	453	0.960
November (1-20)	870	340	683	1.447

MONTHLY DISCHARGE OF ST. MARY RIVER, AT KIMBALL, ALTA.
—*Continued*

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1910				
April	2,450	500	1,068	2.26
May	2,820	1,505	2,206	4.67
June	2,985	1,520	2,208	4.68
July	1,655	750	1,176	2.49
August	775	345	562	1.19
September	740	335	544	1.15
October	1,655	705	1,114	2.36
November	910	495	711	1.50
1911				
January	220	194	210	0.44
February	214	167	189	0.40
March	360	131	196	0.41
April	1,188	250	527	1.12
May	3,839	1,074	2,070	4.38
June	4,391	2,388	3,651	7.74
July	2,714	1,284	1,783	3.77
August	1,420	684	1,044	2.21
September	2,080	684	1,377	2.92
October	1,030	390	676	1.43
November	405	286	334	0.70
December	308	128	190	0.40
1912				
January	208	128	171	0.362
February	174	130	138	0.292
March	131	129	130	0.275
April	700	169	493	1.04
May	3,330	700	1,966	4.16
June	2,810	1,895	2,295	4.86
July	2,200	1,238	1,644	3.48
August	1,262	600	882	1.87
September	620	365	547	1.16
October	532	320	423	0.896
November	570	413	496	1.05
December	382	174	246	0.521
1913				
January	202	95	158	0.335
February	146	101	129	0.273
March	226	135	191	0.405
April	1,240	238	749	1.587
May	5,260	902	1,912	4.051
June	5,380	3,240	4,519	9.574
July	3,620	1,340	2,024	4.288
August	1,690	830	1,162	2.462
September	816	372	542	1.148
October	576	364	448	0.949
November	416	266	371	0.786
December	312	78	190	0.403

MONTHLY DISCHARGE OF ST. MARY RIVER, AT KIMBALL, ALTA.
—Continued

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1914				
January	215	77	128	0.271
February	130	70	101	.214
March	248	98	184	0.390
April	1,129	265	637	1.350
May	2,834	1,092	2,230	4.725
June	3,120	1,742	2,331	4.939
July	1,989	840	1,433	3.036
August	840	543	719	1.523
September	818	410	584	1.237
October	1,255	671	840	1.780
November	1,012	375	713	1.510
December	485	183	259	0.549
1915				
January	186	149	168	.356
February	148	93	117	.248
March	265	108	157	.333
April	1,018	212	575	1.220
May	2,215	1,270	1,645	3.490
June	2,670	1,461	2,251	4.770
July	2,514	1,240	1,722	3.648
August	1,360	1,360	969	2.053
September	1,694	1,694	842	1.784
October	810	810	579	1.227
November	464	464	405	.858
December	347	347	243	.515

Lee Creek

Lee creek, a tributary of the St. Mary river, becomes a torrent at certain seasons; it receives its flow principally from the precipitation of the northern slope of Chief mountain. Its general direction is northeast. A possible power-site is available at Cardston, Alta., with intake at the "Cañon," four miles distant. A head of approximately 127 feet could be obtained, but the power available would be small and the development cost per horse-power high. A gauging station was established on this creek at Cardston by the Irrigation branch of the Department of the Interior in 1909. The following is a summary of discharges since that year:

MONTHLY DISCHARGE OF LEE CREEK, AT CARDSTON,* ALTA.
(Drainage area, 118 square miles.)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1909				
June (28-30)	198.0	198.0	198.0	
July (1-26)	230.0	48.0	120.7	1.02
August (11-31)	55.0	23.0	35.9	.30
September	39.0	10.0	19.7	.167
October	13.5	7.0	10.1	.085
November (1-10)	16.5	7.0	11.3	.096
1910				
April	50.8	23.8	30.6	.26
May	138.0	19.8	60.6	.51
June	117.8	23.0	45.8	.39
July	25.0	4.0	8.8	.075
August	14.8	2.0	60.9	.52
September	118.2	14.8	63.7	.54
October	124.0	25.0	49.2	.42
1911				
May	1,400	242	357	3.03
June	464	140	242	2.05
July	185	49	83.3	0.706
August	206	56	90.8	0.770
September	590	43	244	2.07
October (1-14)	144	94	124	1.05
1912				
August	56	13	28.7	0.244
September	34	25	25.6	0.217
October	45	25	26.2	0.222
November	45	15	27.0	0.229
December	21	10	16.5	0.139
1913				
January	14.0	16.3	9.09	0.077
February	18.0	10.6	13.00	0.110
March	84.0	20.0	59.30	0.502
April	653.0	86.0	293.00	2.480
May	318.0	123.0	224.00	1.900
June	428.0	76.0	180.00	1.530
July	204.0	34.0	75.40	0.639
August	130.0	22.0	37.60	0.319
September	26.0	14.0	16.90	0.143
October	84.0	14.0	32.30	0.274

* This station was discontinued after 1913. A new station has been established at Layton ranch, a short distance upstream.

MONTHLY DISCHARGE OF LEE CREEK, AT LAYTON RANCH
(Drainage area, 92 square miles.)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1914				
January	24.0	7.2	15.4	0.167
February	13.9	5.2	9.2	0.100
March	26.0	9.5	21.0	0.228
April	163.0	31.0	82.0	0.891
May	163.0	76.0	127.0	1.380

MONTHLY DISCHARGE OF LEE CREEK, AT LAYTON RANCH—*Con.*

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1914—(*Cont.*)				
June	149.0	72.0	94.0	1.020
July	61.0	12.8	34.0	0.370
August	61.0	8.5	20.0	0.217
September	25.0	12.2	16.7	0.182
October	178.0	12.8	65.0	0.707
November	94.0	13.3	60.0	0.652
December	20.0	13.2	16.5	0.179
1915				
January	23	13	17	.188
February	15	12	14	.149
March	90	9	26	.282
April	117	45	62	.680
May.	346	90	175	1.900
June	560	103	359	3.902
July	260	56	151	1.641
August	330	27	92	1.000
September	336	26	71	.774
October	126	50	91	.990
November	76	42	56	.612
December	62	26	36	.391

Belly River

The Belly river rises in the mountains of northern Montana. It is augmented in the United States by the Middle Fork and by the North Fork in Canada. Below the junction with the latter, the river flows in a winding, north-easterly course as far as the confluence with Oldman river.* It drains in area of 1,420 square miles.

The topography of the basin is varied, ranging from forested, mountainous regions in its upper part, to rolling prairie near the boundary, and level prairie near the mouth of the river. As yet, very little use has been made of its waters. Utilization would naturally be in connection with irrigation, but a possible power-site has been reported to exist near section 33, township 8, range XXIV, where it is said that 1,200 h.p. could be developed. In the upper regions, where water could be diverted easily, it is not required for irrigation purposes. There are, however, a number of sites where power can be developed. Irrigation would be an expensive undertaking farther downstream. The Alberta Railway and Irrigation Co. may construct a canal from the Belly river to supply its irrigation system if the St. Mary river is found to be insufficient for that purpose.

The Irrigation branch of the Department of the Interior established a gauging station on this river at Standoff, Alta., in 1909. The following is a summary of the discharges observed at this station:

*By a recent decision of the Geographic Board, the name Oldman is applied to the main stream from the confluence of the Belly, downstream to its junction with the Bow.

MONTHLY DISCHARGE OF BELLY RIVER, AT STANDOFF, ALTA.
(Drainage area, 461 square miles.)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1909				
May (26-31)	2,245	1,975	2,086.7	4.54
June	3,330	1,350	2,518.8	5.46
July	1,975	655	1,134.0	2.46
August	1,350	310	608.2	1.32
September	310	205	267.8	.58
October	255	132	189.3	.41
1910				
April	1,430	340	788	1.71
May	1,200	460	852	1.85
June	990	460	682	1.48
July	615	285	439	0.952
August	285	122	220	0.478
September	765	100	410.8	0.891
October	788	305	494	1.07
1911				
January	98	40	60.7	0.131
February	138	52	88.3	0.192
March (1-18 and 24-31)	2,662	138	394	0.855
April	683	122	298	0.646
May	2,466	487	1,043	2.26
June	2,025	1,051	1,454	3.15
July	1,015	453	641	1.39
August	973	287	534	1.16
September	2,162	287	955	2.07
October	372	187	266	0.577
November (1-4 and 27-30)	132	126	128	0.278
December (1-13)	134	107	127	0.275
1912				
January	88	61	78	0.169
February	85	52	75	0.163
March (1-24)	62	54	57	0.124
April (16-30)	313	287	297	0.645
May	1,560	287	860	1.86
June	954	726	851	1.85
July	906	561	675	1.46
August	521	216	321	0.696
September	192	140	171	0.371
October	372	117	227	0.492
November	361	93	249	0.540
1913				
January	68	44	56.4	0.122
February	75	58	67.1	0.146
March	96	64	80.7	0.175
April	678	93	427.0	0.926
May	2,380	317	810.0	1.760
June	1,834	840	1,391.0	3.020
July	1,271	395	706.0	1.530
August	804	323	457.0	0.991
September	323	100	186.0	0.403
October	461	100	204.0	0.443
November	195	124	156.0	0.338
December	144	105	128.0	0.277

DISCHARGE OF BELLY RIVER, AT STANDOFF, ALTA.—*Continued*

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1914				
January	147	45	93	0.202
February	67	29	50	0.108
March	180	63	98	0.213
April	606	108	357	0.774
May	1,604	478	872	1.890
June	1,338	544	888	1.930
July	866	359	571	1.240
August	508	224	320	0.694
September	420	151	256	0.555
October	961	289	450	0.976
November	466	121	251	0.544
December	137	66	78	0.169
1915				
January	82	55	67	.145
February	62	54	57	.124
March	200	49	100	.217
April	514	154	274	.584
May	1,231	413	679	1.472
June	2,700	570	1,401	3.039
July	1,939	442	870	1.887
August	2,100	302	578	1.254
September	1,210	302	452	.980
October	681	333	437	.948
November	328	153	244	.529
December	141	45	81	.176

Waterton Lake

A possible power-site is situated between the upper and lower portions of this lake, at a place called the Narrows. The banks are only 375 feet apart and a 50-foot dam could be erected, but the cost of development would be rather high. A gauging station was established in 1908, by the Irrigation branch of the Department of the Interior, at Waterton Mills, on the Waterton river, the outlet of the lake. The following is a summary of discharges since that year:

DISCHARGE OF WATERTON RIVER, AT WATERTON MILLS, ALTA.
(Drainage area, 214 square miles.)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1908				
June (10-30)	7,750	2,325	3,811.4	17.81
July	3,040	660	1,852.6	8.66
August	780	335	485.3	2.27
September	335	200	234.8	1.09
October (1-17)	660	280	426.8	1.99

MONTHLY DISCHARGE OF WATERTON RIVER, AT WATERTON MILLS, ALTA.—*Continued*

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1909				
April (9-30)	280	200	242.5	1.13
May	4,090	280	1,527.3	7.14
June	6,414	2,800	4,707.7	22.00
July	3,555	905	2,140.8	10.00
August	2,105	395	782.9	3.66
September	395	235	314.7	1.47
October	235	200	221.5	1.03
November (1-25)	555	200	425.0	1.99
1910				
April	2,650	520	1,106	5.16
May	2,650	1,485	2,145	10.00
June	2,925	1,165	1,819	8.50
July	1,165	450	830	3.88
August	450	248	347	1.62
September	1,030	248	591	2.76
October	1,770	600	1,061	4.96
November	970	485	731	3.42
1911				
April (19-30)	2,974	285	1,035	4.84
May	3,022	1,128	1,650	7.71
June	4,102	2,075	3,106	14.50
July	1,999	720	1,136	5.30
August	1,089	422	744	3.47
September	1,818	394	1,255	5.86
October	800	134	457	2.14
November (1-4)	134	128	132	.62
1912				
January	551	78	245	1.14
February	470	110	217	1.01
March	130	109	112	.52
April	560	131	364	1.70
May	2,535	533	1,509	7.05
June	2,245	1,357	1,744	8.15
July	1,442	835	1,205	5.63
August	799	258	454	2.12
September	310	242	270	1.26
October	497	224	330	1.54
November	600	262	371	1.73
December	250	127	181	.84
1913				
January	144	111	121	.56
February	112	106	110	.51
March	113	108	110	.51
April	876	114	373	1.74
May	5,185	525	1,577	7.37
June	5,149	2,006	3,383	15.80
July	2,389	681	1,133	5.29
August	888	379	638	2.98
September	408	188	273	1.28
October	543	192	384	1.79
November	416	171	267	1.25
December	440	130	179	.84

MONTHLY DISCHARGE OF WATERTON RIVER, AT WATERTON MILLS, ALTA.—*Continued*

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1914				
January	214	114	161	0.752
February	165	109	134	0.626
March	161	106	131	0.612
April	1,135	186	611	2.85
May	2,490	1,012	1,913	8.94
June	2,908	1,256	1,993	9.31
July	1,352	445	905	4.23
August	551	298	431	2.01
September	576	256	394	1.84
October	1,454	510	856	4.00
November	806	303	536	2.50
December	503	93	201	0.939
1915				
January	148	74	111	.519
February	103	82	91	.425
March	134	74	92	.430
April	1,020	148	548	2.561
May	1,890	1,006	1,369	6.397
June	2,142	1,294	1,713	8.005
July	1,618	721	981	4.584
August	801	341	496	2.318
September	630	320	507	2.369
October	640	445	539	2.519
November	630	180	384	1.793
December	234	146	197	.920

Oil Creek

Oil creek, a tributary of Waterton lake, receives its flow from the melting snow of the surrounding peaks. The flow is very much dependent upon the temperature, and a hot, rainy summer results in a greatly diminished water supply before autumn.

Above the foothills, where there is a fall of about 30 feet, the creek flows through a cañon in a series of cascades. Power could be developed at this point and, with one-half mile of pipe, an effective head of 250 feet could be obtained. The minimum flow has been estimated at 14 second-feet, so that 400 horse-power would be available. The development cost would not be high.

The following are miscellaneous discharges taken by the Irrigation branch of the Department of the Interior near the mouth of this creek:

Date	Discharge in second-feet	Date	Discharge in second-feet
1906		August 30	30
September 12	29	September 16	28
1907		October 1	21
July 18	216	November 4	26
1908		1910	
September 4	14	June 29	154
1909		July 15	67
		August 12	22
July 24	85	September 5	22

Blakiston Brook

Blakiston brook is another tributary of Waterton lake, receiving its water from the melting snow in the mountains. The valley is narrow, averaging one-quarter mile in width. Power might be developed by means of an intake at section 5, township 2, range XXX, with a canal and pipe line, over five miles in length, to Waterton lake. An effective head of 158 feet would thus be rendered available. The minimum flow had been estimated at 40 second-feet, but a later discharge measurement, taken on August 12, 1910, gave only 28·4 second-feet. Assuming the latter calculation to be correct, nearly 500 h.p. would be available during the summer.

Tib Creek

Tib creek is a tributary of the Belly river, which it joins two and one-half miles north of the international boundary. It rises in the mountains and has a narrow valley, varying from one-third to one-half mile in width, and cañon-like in places. There is a possible power-site, with the intake a short distance north of the boundary, and the power-house situated four miles below. A head of 349 feet could be obtained. The minimum flow has been estimated at 35 second-feet, giving 1,364 horse-power.

Willow Creek

Willow creek is one of the more important tributaries of Oldman river. It rises in the northern Porcupine hills and flows south-easterly to its confluence with the Oldman. The distance in a straight line, from its head-waters to its mouth, is approximately 40 miles, but, by following the river, whose lower course is very tortuous, this is greatly increased.

The following is a summary of discharges at a gauging station established near Macleod by the Irrigation branch of the Department of the Interior:

DISCHARGE OF WILLOW CREEK, NEAR MACLEOD, ALTA.
(Drainage area, 1,016 square miles.)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1909				
July	946	94	295.1	.294
August	350	60	133.5	.133
September	60	34	44.4	.044
October	46	34	41.4	.041

DISCHARGE OF WILLOW CREEK, NEAR MACLEOD.—*Continued*

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1910				
April	45	35	40.67	.040
May	68	35	52.58	.052
June	35	7.5	23.48	.023
July	7.5	1.1	3.2	.0032
August	4.3	.9	2.72	.0027
September	82	5.2	46.59	.046
October	70	23.9	47.63	.047
1911				
March (22-31)	292	65	185	.184
April	131	33.5	76.9	.076
May	881	63.9	211	.209
June	460	92.8	199	.198
July	144	42.5	72.5	.072
August	1,312	48	309	.305
September	1,413	113	515	.512
October	253	48	136	.135
November (1-15)	174	81	136	.135
1912				
April (20-30)	298	225	255.9	.25
May	398	238	305.0	.30
June	1,360	134	381.4	.38
July	952	298	493.3	.49
August	581	143	284.6	.28
September	233	103	137.3	.14
October	165	104	120.6	.12
November (1-15)	143	95.5	114.9	.11
1913				
April (7-31)	755	223	490	0.482
May	563	202	397	0.391
June	637	183	317	0.312
July	644	189	300	0.295
August	422	105	187	0.184
September	142	62	92	0.091
October	92	76	85	0.084
1914				
March (19-31)	102	41.0	65	.064
April	448	118.0	182	.180
May	193	118.0	156	.154
June	448	73.0	151	.149
July	358	21.0	91	.090
August	89	11.0	31	.031
September	37	12.2	22	.022
October	288	15.5	125	.123
1915				
March (22-31)	291	108	207	.204
April	166	108	130	.128
May	1,804	128	994	.981
June	3,959	773	1,609	1.588
July	2,012	800	1,226	1.210
August	1,228	254	543	.536

Castle (Southfork) River

This river rises in numerous mountain streams and, flowing in a north-easterly direction, enters the Oldman river near Cowley, Alta.

Three possible power sites are reported on this river. The first is at sec. 35, tp. 6, r. I, w. of 5th, where a head of 45 feet could be created by a dam 400 feet in length. The second is at sec. 6, tp. 6, r. I, w. of 5th, where a head of 100 feet or more could be created by a dam in a narrow cañon. The third is at sec. 24, tp. 6, r. II, w. of 5th, where a head of 40 feet could be created by a dam 250 feet in length.

Assuming a minimum flow of 70 second-feet, 350 h.p., 800 h.p., and 320 h.p., respectively, would be available at these three sites.

A gauging station was established by the Irrigation branch of the Department of the Interior on this river, near Cowley, in 1909. The following is a summary of discharges since that year:

MONTHLY DISCHARGE OF CASTLE RIVER, NEAR COWLEY, ALTA.
(Drainage area, 374 square miles)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1909				
August (5-31)	980	350	631	1.69
September	350	230	274.8	.74
October	230	200	203.9	.55
1910				
April	2,605	345	1,115	2.98
May	2,790	1,215	1,908	5.15
June	2,250	880	1,420	3.8
July	880	240	497.6	1.33
August	240	155	204	0.547
September	695	155	371	0.993
October	1,145	465	722.8	1.93
1911				
January	100	69	86.5	0.237
February	241	85	118	0.316
March	251	186	226	0.604
April	2,450	178	743	1.99
May	5,555	1,388	2,275	6.08
June	5,050	2,080	3,675	9.83
July	1,990	473	933	2.49
August	1,575	424	726	1.94
September	6,130	404	1,911	5.11
October	861	374	566	1.51
November	4,430	224	867	2.32
December	237	192	222	0.567
1912				
January	195	85	107	0.286
February	89	71	81.8	0.219
March	204	76	93.1	0.249
April	1,336	204	682	1.82
May	2,730	732	1,845	4.93
June	2,062	910	1,433	3.83

MONTHLY DISCHARGE OF CASTLE RIVER, NEAR COWLEY, ALTA.
—*Continued*

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1912—(*Cont.*)				
July	1,650	772	1,157	3.09
August	772	290	444	1.19
September	550	235	290	0.775
October	374	235	304	0.813
November	374	180	319	0.853
December	182	77	133	0.356
1913				
January	135	96	119	0.318
February	124	76	98.5	0.263
March	107	76	88	0.235
April	1,184	112	612	1.640
May	5,016	779	1,954	5.220
June	4,859	1,565	2,709	7.240
July	1,640	450	789	2.110
August	720	298	426	1.140
September	321	232	265	0.709
October	610	232	395	1.060
November	370	274	345	0.928
December	254	101	138	0.369
1914				
January	186	82	141	.405
February	199	88	164	.471
March	450	105	145	.416
April	1,392	646	907	2.610
May	2,610	1,010	1,781	5.120
June	2,930	891	1,545	4.440
July	1,040	300	596	1.710
August	810	210	352	1.010
September	520	250	311	.894
October	2,138	350	934	2.680
November	828	448	605	1.740
December	490	218	297	.853
1915				
January	305	160	221	.635
February	173	107	136	.391
March	242	106	143	.411
April	1,190	219	722	2.075
May	4,330	1,714	2,353	6.761
June	3,055	1,570	2,150	6.178
July	1,510	690	980	2.816
August	1,220	325	563	1.618
September	540	310	419	1.204
October	575	480	528	1.517
November	510	205	336	.966
December	231	162	196	.563

Crowsnest River

The valley of Crowsnest river, which is a tributary of Oldman river, is well-defined, consisting of rolling slopes with occasional mountains. It is free from cut banks and is partly timbered and partly open prairie. The banks of the river seldom exceed 10 or 12 feet in height. A possible power-site is situated at the fall, near Lundbreck. The

fall is caused by a fault in the hard sandstone formation, which lies practically horizontal above and below the fall. This power site is in sec. 26, tp. 7, R. II, west of fifth meridian. The natural fall is 31 feet and a dam 9 feet in height would give a total head of 40 feet, which, with an estimated minimum flow of 60 second-feet, would give 270 h.p. The cost of development would be moderate.

A gauging station was established at Lundbreck, Alta., by the Irrigation branch of the Department of the Interior in 1907. The following is a summary of discharges at this station since 1908:

DISCHARGE OF CROWSNEST RIVER, NEAR LUNDBRECK, ALTA.
(Drainage area, 263 square miles)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1908				
September (16-30)	167	142	152	0.578
October	167	142	149	0.568
1909				
April (15-30)	425	82	235	0.893
May	1,945	82	847	3.22
June	2,395	690	1,425	5.42
July	2,665	380	785	2.98
August	1,245	226	439	1.67
September	226	167	187	0.712
October	167	119	143	0.544
November	297	142	175	0.666
1910				
April	839	175	445	1.69
May	709	439	583	2.22
June	539	350	450	1.71
July	350	175	245	0.933
August	175	105	138	0.523
September	149	105	134	0.510
October	278	149	219	0.833
November (1-26)	309	162	188	0.715
1911				
January	89	76	85.2	0.324
February	99	87	90.9	0.346
March	155	88	111	0.422
April	1,090	115	352	1.34
May	2,455	615	976	3.71
June	1,657	615	996	3.79
July	627	259	736	2.80
August	858	192	345	1.31
September	1,328	186	559	2.12
October	344	183	257	0.977
November	555	76	175	0.677
December	105	57	78.9	0.30

DISCHARGE OF CROWSNEST RIVER, NEAR LUNDBRECK.—*Continued*

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1912				
January	106	90	97.5	0.371
February	94	76	86.1	0.328
March	160	81	97	0.369
April	531	110	324	1.23
May	681	330	530	2.02
June	1,300	339	488	1.86
July	681	330	487	1.85
August	373	162	239	0.909
September	168	134	151	0.574
October	162	122	132	0.502
November	205	117	145	0.552
December	205	68	105	0.399
1913				
January	90	67	77.8	0.296
February	82	60	68.6	0.261
March	91	60	76.7	0.292
April	959	90	411	1.560
May	1,224	403	706	2.680
June	1,149	448	717	2.730
July	499	216	330	1.250
August	324	168	240	0.912
September	253	122	164	0.624
October	232	112	148	0.563
November	139	99	120	0.456
December	117	86	103	0.392
1914				
January	98	72	84	.32
February	78	65	72	.27
March	121	69	91	.35
April	625	119	333	1.27
May	855	244	589	2.24
June	610	332	438	1.67
July	395	184	271	1.03
August	244	130	177	.67
September	221	130	169	.64
October	580	204	310	1.18
November	315	158	225	.86
December	154	106	123	.47
1915				
January	150	104	131	.475
February	101	67	79	.286
March	124	68	95	.344
April	446	104	307	1.112
May	1,467	578	861	3.120
June	886	455	600	2.174
July	754	330	458	1.660
August	425	175	251	.903
September	185	146	161	.583
October	188	144	160	.580
November	170	93	136	.492
December	106	52	92	.333

Bow Lake, Showing Glacier

Ghost River

CHAPTER IX

Milk River

Milk river is the only stream of importance in Canada belonging to the Missouri drainage basin. It rises in the eastern slope of the foothills in the Blackfoot Indian reserve, in the United States. Its headwaters descend in two main streams, known as the North and South branches. The North branch flows north-easterly for a distance of about 15 miles, and enters Canada in tp. 1, R. XXIII, west of the fourth meridian; thence, northerly and easterly to its junction with the South branch.

The South branch enters Canada in tp. 1, R. XX, west of the fourth meridian; thence northeast to join the North branch. From the confluence of the two branches, Milk river flows easterly and south-easterly, crossing the boundary into the United States, in tp. 1, R. V, west of the fourth meridian.

Throughout its course in Canada, Milk river flows through a well-defined valley, bordered on each side by a range of hills. Bare prairie land comprises the entire watershed. The river receives several small tributaries, all of which discharge a considerable volume of water during the spring freshets. Usually they become dry early in July, and have no considerable discharge again until late autumn, when some of them have a small flow for perhaps a month before winter.

The general conditions of flow in the basin of the Milk river are typical of those in most watersheds devoid of tree growth, *viz.*, extreme floods during the freshet period and small flow during the summer months.* From its headwaters to the crossing in sec. 1, tp. 1, R. V, the total area of its watershed is 2,514 square miles. Of this area, two-thirds are in Canada and one-third in the United States.

The following are summaries of discharges at two of the gauging stations established by the Irrigation branch of the Department of the Interior:

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*Respecting the diversion of a portion of the waters of the St. Mary to the Milk, see pp. 158-159.

MONTHLY DISCHARGE OF MILK RIVER, AT SPENCER'S LOWER RANCH, ALTA.

(Drainage area, 2,514 square miles at boundary line.)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1910				
April (14-30)	271.5	169	218.6	.087
May	279.5	120	184.9	.074
June	209.5	43.5	108	.043
July	55.5	5.5	27	.011
August	11.0	3	4.6	.002
September	68.0	12.3	43.8	.017
October	52.0	36	42.2	.017
1911				
March (16-31)	981	238	433	.172
April	444	99	285	.113
May	1,013	170	363	.144
June	1,655	129	348	.138
July	853	87	230	.092
August	195	71	116	.046
September	1,409	70	422	.168
October	350	124	200	.080
November (1-7)	229	101	168	.067
1912				
April (6-30)	2,008	280	580	.231
May	909	191	318	.126
June	319	59	136	.054
July	176	64	113	.045
August	100	39	59.6	.023
September	83	35	60.4	.024
October	90	65	78.1	.031
November (1-16)	83	72	76.6	.030
1913				
April	1,858	60	944	.375
May	937	363	530	.211
June	702	179	320	.127
July	739	69	180	.072
August	216	52	85	.034
September	51	22	32	.013
October	98	46	66	.026
November	112	59	81	.032
1914				
March (21-31)	550	78.0	340.0	.135
April	1,064	156.0	501.0	.199
May	254	98.0	158.0	.063
June	300	55.0	103.0	.041
July	69	0.9	26.0	.010
August	44	0.0	7.3	.003
September	122	6.3	23.0	.009
1915				
March (15-31)	1,750	60	542	.216
April	1,367	100	300	.119
May	540	100	224	.089
June	1,220	180	550	.219
July	610	194	321	.127
August	515	103	204	.081
September	515	97	196	.078
October	252	136	193	.077
November	156	72	115	.046
December	65	25	42	.017

MONTHLY DISCHARGE OF SOUTH BRANCH OF MILK RIVER, AT MACKIE RANCH, ALTA.

(Drainage area, 441 square miles.)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1910				
April	239.5	80	137.7	.312
May	242	75	121.2	.275
June	242	34	71.4	.162
July	41	1.6	15	.034
August	14	1	4.43	.010
September	46.5	12.5	30.8	.070
October	36.5	24	29.9	.068
November (1-27)	56.5	25	37.98	.086
1911				
April (17-30)	341	198	258	.585
May	961	158	275	.624
June	982	100	254	.576
July	223	44	90	.204
August	82	29	54	.122
September	446	34	141	.320
October	97	59	74	.168
November (1-3)	85	83	84	.190
1912				
April (5-30)	449	157	222	.503
May	669	121	209	.474
June	121	44	78.8	.179
July	110	45	63.6	.144
August	59	21	35.6	.081
September	42	21	32.8	.074
October	48	22	42.6	.097
November (1-16)	45	39	42.4	.096
1913				
April (6-30)	554	163	430	0.975
May	456	185	332	0.753
June	424	106	216	0.490
July	359	46	100	0.227
August	106	18	51.3	0.118
September	36	9.6	18.4	0.042
October	140	30	68.4	0.155
1914 (Drainage area, 504 square miles)				
April (4-10)	436.0	227.0	292.0	.579
May (6) (20-31)	156.0	68.0	102.0	.202
June	131.0	30.0	60.0	.119
July	40.0	.6	15.0	.030
August	39.0	Nil	10.3	.020
September	19.4	6.4	11.4	.023
October	215.0	7.2	70.0	.139
1915				
April	124	40	73	.145
May	288	42	130	.258
June	858	53	249	.494
July	377	63	139	.276
August	167	31	61	.121
September	462	31	130	.258
October	126	74	93	.185

CHAPTER X

Bow River below Calgary

For fourteen and one-half miles below Calgary, the Bow river flows almost due south near the 114th meridian, thence eastward for a distance of eight miles to its confluence with the Highwood. The banks are about 100 feet in height, and although scarped in some places, often bear groves of cottonwood. The bottoms are not of great area but, in many cases, are well adapted to farming; the entire country shows an excellent growth of grass.

Pine cañon extends for about nine miles below the mouth of the Highwood. The banks here are almost 200 feet in height. They are steep and generally scarped but, in the hollows, heavily wooded with spruce and broad-leafed trees. This is the easternmost occurrence of coniferous trees on the Bow. From this point the valley again widens and the banks are scarped only at the bends of the river. They are at first much lower, often only from 50 to 60 feet high, but, approaching Blackfoot crossing, they gradually rise and attain a height of from 100 to 150 feet. The greater portion of this section of the river is moderately direct in its course, but, before reaching Blackfoot crossing, it describes several great curves and many minor bends. The stream is wide and shallow, with innumerable sloughs and channels, and, in two parts of its course—twelve and two miles respectively above the crossing—forms a complete plexus of islands and shoals.

The elevation of the Bow river, above the Bassano dam, is 2,563 feet, as compared with 3,363 feet at Calgary. The distance traversed by the river is approximately 103 miles, and the average descent 7·8 feet per mile. The most dangerous rapids occur in a reach a few miles in length, below the mouth of Fish creek, and are both rough and strong.

A large volume of water is diverted from the Bow river for irrigation purposes, chiefly by the Canadian Pacific Railway Company and the Southern Alberta Land Company.

The Southern Alberta Land Company has a dam and reservoir near Namaka. These works were practically completed in 1913. It is proposed to irrigate by this system about 300,000 acres.

The Canadian Pacific Railway Company diverts water at two points, one just east of the city of Calgary and the other three miles southwest of Bassano. The first system has been in operation for several years and distributes water over the western section of the irrigation block which extends east as far as Gleichen. The works at Bassano comprise a very large, earth fill dam and concrete spillway, which were completed in 1913. This system is to serve the section of the irrigation block east of Bassano. It is proposed to irrigate altogether about 1,000,000 acres of land.

The Irrigation branch of the Department of the Interior has had stream-measurement stations on this river for several years. The following tables have been compiled from the records:—

MONTHLY DISCHARGE OF BOW RIVER, AT CALGARY, ALTA.

(Drainage area, 3,900 square miles.)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1908				
May (10-31)	7,093	5,063	5,954.9	1.53
June	18,880	9,050	13,701.5	3.51
July	13,134	6,631	10,801.1	2.77
August	6,873	4,496	5,652.2	1.45
September	4,496	2,904	3,648.2	.94
October (1-28)	2,904	1,940	2,400.2	.62
1909				
April (20-30)	1,620	1,280	1,354.5	.35
May	10,126	1,280	4,176.2	1.07
June	20,306	10,069	14,527.4	3.73
July	22,051	8,060	12,263.2	3.15
August	8,680	4,314	5,878.9	1.51
September	4,758	2,490	3,703.0	.95
October	3,106	1,880	2,422.9	.62
November (1-6)	1,880	1,880	1,880.0	.48
1910				
April (6-30)	5,311	760	1,984	.51
May	12,317	3,871	6,867	1.76
June	14,251	7,823	10,655	2.73
July	10,529	5,431	8,513	2.18
August	7,915	3,689	5,646	1.45
September	4,039	3,172	3,662	.94
October	3,740	2,330	3,164	.81

NOTE.—The discharges of the Canadian Pacific Railway Company's canal have been added to those of Bow river at Cushing bridge, in this table.

MONTHLY DISCHARGE OF BOW RIVER, NEAR CALGARY, ALTA.
(At Langevin bridge)
(Drainage area, 3,056 square miles.)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1910—(*Cont.*)				
November (29-30)	1,230	1,180	1,205	.39
December	1,660	700	1,205	.39
1911				
January (1-4, 21-30)	1,040	600	880	.29
February	1,005	796	914	.30
March	940	810	857	.28
April	2,288	860	1,292	.42
May	3,720	1,496	2,676	.87
June	16,460	5,970	11,434	3.74
July	13,730	7,000	9,459	3.10
August	15,130	5,250	7,396	2.42
September	6,420	3,160	4,452	1.46
October	3,270	1,800	2,424	.79
November	2,200	960	1,609	.53
December	1,070	650	774	.25
1912				
January	1,670	680	1,109	0.36
February	1,160	980	1,048	.34
March	1,640	825	1,030	.34
April	2,170	1,040	1,571	.51
May	5,485	1,620	3,432	1.12
June	13,894	2,420	8,185	2.68
July	15,210	6,890	10,772	3.52
August	11,121	6,006	8,169	2.68
September	7,160	3,310	4,847	1.58
October	3,505	2,240	3,064	1.00
November	2,562	1,274	2,076	.68
December	1,720	580	985	.32
1913				
January	1,270	1,003	1,118	.366
February	1,250	908	1,124	.368
March	1,539	864	1,192	.390
April	2,380	1,180	1,663	.544
May	9,070	1,565	3,201	1.05
June	14,670	8,470	11,557	3.78
July	10,910	4,870	7,651	2.50
August	9,270	5,126	6,825	2.23
September	8,030	3,163	4,561	1.49
October	3,249	2,120	2,635	.862
November	2,505	1,268	1,951	.638
December	2,234	890	1,794	.587
1914				
January	1,360	800	1,045	.342
February	1,055	845	945	.309
March	1,144	908	1,034	.338
April	1,870	1,150	1,498	.490
May	5,470	1,660	3,700	1.211
June	14,290	4,990	10,208	3.340
July	13,390	5,500	9,645	3.156
August	6,010	3,725	4,750	1.554
September	3,775	2,500	2,926	.958

MONTHLY DISCHARGE OF BOW RIVER, NEAR CALGARY, ALTA.
—*Continued*

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1914—(*Cont.*)				
October	3,450	2,095	2,772	.907
November	2,170	1,470	1,767	.578
December	1,720	920	1,111	.363
1915 (Drainage area, 3,113 square miles)				
January	1,320	1,050	1,225	.394
February	1,267	1,150	1,197	.385
March	1,504	1,280	1,400	.450
April	1,993	1,194	1,605	.516
May	5,790	2,480	4,459	1.432
June	28,130	5,460	10,440	3.354
July	18,590	10,560	14,470	4.648
August	11,560	6,190	8,305	2.668
September	6,280	3,079	4,115	1.322
October	3,058	2,256	2,680	.861
November	2,373	1,400	1,746	.561
December	1,485	955	1,269	.408

DISCHARGE OF BOW RIVER, NEAR MORLEY, ALTA.*

(Drainage area, 2,111 square miles.)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1910				
May (25-31)	10,440	6,500	8,473	4.01
June	13,090	6,115	9,544	4.52
July	9,640	5,760	7,859	3.72
August	6,635	2,952	4,829	2.29
September	3,210	2,460	2,794	1.32
October	2,986	1,972	2,510	1.19
November	1,930	950	1,519	.72
December	1,510	770	1,111	.53
1911				
January (21-31)	680	512	593	.281
February	704	564	615	.291
March	920	560	687	.325
April	1,262	340	827	.392
May	3,400	1,240	2,229	1.06
June	13,545	5,040	10,184	4.82
July	10,825	6,150	8,059	3.82
August	7,440	4,076	5,759	2.73
September	5,160	2,240	3,501	1.66
October	2,272	1,350	1,840	.872
November (1-8, 27-30)	1,734	724	1,308	.620

*1911, the Morley station was transferred to Kananaskis, as the operation of the Calgary Power Company's plant caused the records at Morley to be unsatisfactory.

MONTHLY DISCHARGE OF BOW RIVER, NEAR KANANASKIS
(Drainage area, 1,601 square miles.)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1912				
March (10-31)	640	570	580.50	.36
April	710	546	627.00	.39
May	4,389	635	2,199.68	1.37
June	8,100	1,894	5,475.13	3.42
July	8,308	4,432	6,130.0	3.82
August	7,947	4,100	5,923.0	3.70
September	4,604	2,320	3,294.0	2.05
October	2,464	1,734	2,158	1.35
November	2,221	710	1,259	.79
December	1,390	300	656	.41
1913				
January	790	640	703	0.439
February	770	570	679	0.424
March	1,065	670	839	0.524
April	2,008	820	1,285	0.083
May	8,378	1,040	2,546	1.58
June	11,150	7,165	8,776	5.48
July	7,975	3,509	5,540	3.46
August	6,446	3,734	5,049	3.15
September	5,536	1,976	3,381	2.11
October	2,820	1,440	2,026	1.26
November	2,000	1,144	1,507	0.941
December	1,660	1,200	1,398	0.873
1914				
January	1,260	600	859	0.537
February	740	560	717	0.448
March	740	605	670	0.419
April	980	700	821	0.513
May	4,130	1,168	2,584	1.620
June	10,422	2,872	6,932	4.330
July	10,146	4,210	6,957	4.350
August	4,945	2,351	3,536	2.210
September	2,450	1,841	2,136	1.330
October	2,520	1,729	2,159	1.350
November	1,848	860	1,225	0.765
December	990	420	644	.401
1915				
January	816	500	654	.401
February	880	630	803	.492
March	1,365	662	825	.506
April	1,752	728	1,093	.670
May	3,670	1,860	2,570	1.580
June	13,780	3,290	5,428	3.330
July	13,276	5,924	8,059	4.940
August	6,875	4,268	5,134	3.150
September	4,125	1,833	2,539	1.560
October	2,010	1,725	1,855	1.140
November	1,833	1,220	1,394	.855
December	1,370	865	1,165	.714

The drainage area of the Bow is almost the same near Namaka as near Bassano; the latter is the lower. The following summaries of discharges are from the lowest points on the Bow where regular observations are taken:

MONTHLY DISCHARGE OF BOW RIVER, NEAR NAMAKA, ALTA.

Month	Discharge in second-feet		
	Maximum	Minimum	Mean
1910			
March (23-31)	10,195	3,157	6,855.2
April	5,475	1,855	2,576.3
May	12,875	4,209	7,179.3
June	14,670	8,577	10,843.4
July	9,930	5,265	7,909.5
August	7,360	3,569	5,387.7
September	4,290	3,535	3,910.0
October	4,182	2,940	3,597.8

MONTHLY DISCHARGE OF BOW RIVER, NEAR BASSANO, ALTA.
(Drainage area, 7,613 square miles.)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1911				
May	7,950	1,920	4,061	.53
June	20,190	7,950	14,669	1.93
July	17,500	8,160	10,833	1.43
August	22,780	5,060	9,566	1.26
September	10,860	4,080	6,363	.84
October	4,170	2,420	3,286	.43
November (1-6)	2,720	2,070	2,337	.31
1913				
July (20-31)	8,565	5,830	7,453	0.978
August	14,274	6,180	8,449	1.11
September	8,430	3,100	5,032	0.661
October (1-15)	3,700	2,946	3,251	0.427
1914				
June	14,340	8,360	12,021	1.579
July	13,140	4,820	8,705	1.143
August	5,330	3,950	4,658	0.612
September	4,450	1,625	2,750	0.361
October	4,450	2,420	3,138	0.412
November	2,740	1,310	2,228	0.293
December	2,180	550	1,027	0.135
1915				
January	1,800	1,000	1,262	.166
February	1,650	1,200	298	.039
March	3,100	1,300	263	.034
April	3,450	1,100	959	.126
May	17,260	2,115	9,617	1.26
June	69,156	10,600	18,475	2.43
July	43,408	18,580	27,273	3.58
August	22,244	7,600	12,407	1.63
September	9,780	3,950	5,888	.773
October	4,530	2,220	3,131	.411
November	3,550	840	2,211	.290
December	2,160	750	1,357	.178

NOTE.—The monthly summary of discharges for 1912 is not available.

Highwood River

Highwood river is an important tributary of Bow river. It rises in numerous small streams on both sides of Highwood range, and flows in an easterly direction to High River, thence almost due north to its confluence with the Bow. It receives many fairly large tributaries, including Sheep river, Tongueflag and Pekiska creeks. In the foothills adjacent to the mountains the valley of the main stream is a wide depression, with prairie flats and terraced sides. The neighboring hills are partly wooded. The river leaves the Highwood range through a narrow gap or gorge; for a distance of 14 miles, to a point near Mist mountain, the valley contains stretches of prairie, but becomes more generally wooded at the mountain.

The following is a summary of discharges at the gauging station established by the Irrigation branch of the Department of the Interior:

DISCHARGE OF HIGHWOOD RIVER, AT HIGH RIVER, ALTA.
(Drainage area, 746 square miles)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1908				
June (1-27)	9,180	2,365	4,163.6	5.58
August	460	250	342.1	.458
September	272	160	195.5	.262
October	322	160	221.1	.296
1909				
April	375	115	186.6	.249
May	3,805	240	1,568.1	2.10
June	4,400	1,320	2,651.6	3.55
July	2,965	667	1,516	2.02
August	1,205	290	547.6	.734
September	290	140	223.5	.299
October	153	140	145.6	.195
1910				
April	710	110	258.5	.346
May	1,715	405	855.6	1.15
June	1,205	625	953.2	1.28
July*	400	226	398.4	.531
August*	226	155	191.2	.256
September*	540	178	351.3	.471
October*	490	185	341.1	.457

* Includes Little Bow ditch.

DISCHARGE OF HIGHWOOD RIVER, AT HIGH RIVER.—*Continued*

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1911				
March (22-31)†	150	72.6	105	.141
April†	464	51.3	182	.244
May†	2,301	290	790	1.06
June†	3,345	1,130	1,844	2.48
July†	1,339	276	612	.821
August†	2,728	312	860	1.15
September†	1,975	426	984	1.22
October†	594	316	412	.553
November (1-13)†	384	67.8	186	.248
1912				
April	425	242	300	.402
May	1,510	256	732	.982
June	6,720	502	1,275	1.71
July	2,240	920	1,172	1.57
August	1,264	394	627	.840
September	375	240	293	.393
October	265	103	221	.296
November (1-23)	284	98	174	.234
1913				
April	370	282	318	0.426
May	2,220	260	768	1.03
June	2,106	734	1,478	1.98
July	1,646	356	702	0.941
August	642	352	528	0.708
September	431	244	319	0.428
October	405	164	273	0.366
November	271	114	195	0.261
December	121	26	86	0.115
1914				
April (10-30)	365	233	308	.413
May	1,272	365	880	1.180
June	1,921	744	1,209	1.620
July	922	235	550	.737
August	215	131	173	.232
September	220	116	140	.188
October	593	127	293	.393
1915				
January	98	70	85	.114
February	76	69	74	.099
March	132	30	66	.088
April	490	61	255	.342
May	3,416	900	1,968	2.638
June	8,024	1,800	2,879	3.859
July	3,800	1,260	1,973	2.645
August	1,648	335	796	1.067
September	470	250	351	.470
October	464	255	357	.479
November	300	102	173	.232
December	158	126	141	.189

† Includes flow through Little Bow ditch and Lineham's spillway.

Sheep River

Sheep river is the principal tributary of Highwood river. It rises in the outer ranges of the Rocky mountains and foothills and flows easterly to its confluence with the Highwood.

The following is a summary of discharges at the gauging station established by the Irrigation branch of the Department of the Interior near Okotoks:

MONTHLY DISCHARGE OF SHEEP RIVER, NEAR OKOTOKS, ALTA.

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1908				
April (5-30)	880	80	173.5	.277
May	3,400	130	968.8	1.55
June	7,685	880	2,396.6	3.84
July	780	210	444.4	.712
August	210	145	187.4	.300
September	160	100	122.8	.197
October	275	160	191.6	.306
1909				
May (7-31)	3,386	705	2,071.3	3.32
June	3,212	1,008	2,018.5	3.23
July	2,116	348	1,033.8	1.66
August	862	172	318.2	.51
September	172	112	130.1	.181
October	98	72	88.4	.142
1910				
April	203	59	112	.180
May	408	180	251	.403
June	314	180	251	.402
July	180	80	119	.191
August	159	69	115	.184
September	255	107	210	.336
October	203	123	156	.249
1911				
April	804	66	273	.438
May	1,720	182	563	.902
June	1,720	440	855	1.370
July	1,080	194	386	.619
August	2,410	226	853	1.367
September	1,726	352	688	1.103
October	446	222	281	.450
November (1-5)	232	225	230	.369
1912				
April (6-15)	603	239	305	.489
May	701	282	510	.818
June	5,446	282	915	1.467
July	4,711	610	1,682	2.695
August	863	205	387	.620
September	255	141	221	.354
October	435	183	263	.422
November (1-15)	495	104	175	.281

MONTHLY DISCHARGE OF SHEEP RIVER, NEAR OKOTOKS, ALTA.
—Continued

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1913				
April	1,045	54	345	.558
May	901	105	466	.754
June	1,581	352	735	1.190
July	1,341	276	463	.749
August	1,285	190	411	.665
September	315	139	194	.314
October	150	143	148	.239
1914				
April (4-30)	646	131	228	.361
May	789	182	517	.818
June	854	252	563	.890
July	772	120	330	.522
August	167	103	128	.203
September	172	78	108	.171
October	458	135	212	.335
1915				
March (17-31)	307	84	156	.247
April	150	92	124	.196
May	2,979	301	1,330	2.104
June	21,390	1,032	2,871	4.543
July	18,500	296	3,920	6.203
August	2,300	391	847	1.340
September	920	315	466	.737
October	560	270	382	.604

Fish Creek

Fish creek is a tributary of Bow river. Rising between the Sheep and Elbow rivers, it flows in a general easterly direction to its confluence with the Bow, 15 miles below Calgary.

The following is a summary of discharges at the gauging station established by the Irrigation branch of the Department of the Interior near Priddis:

MONTHLY DISCHARGE OF FISH CREEK, NEAR PRIDDIS, ALTA.

(Drainage area, 109 square miles.)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1908				
June (11-30)	496	118	228.6	2.09
July	104	12	53.6	.492
August	40	9	16.7	.153
September	23	6	9.5	.087
October	49	12	22.3	.205
1909				
May (3-31)	556	58	241.0	2.21
June	104	31	58.8	.54
July	182	23	70.2	.64
August	44.5	7.5	15.8	.145
September	9	5	6.7	.061
October	15	6	6.8	.062
1910				
May	11.5	5.5	7.8	.071
June	15.5	1.9	7.23	.066
July	1.9		.48	.004
August	5.5		1.5	.014
September	44.8	5.5	17.0	.156
October	10.5	5.5	6.8	.062
1911				
April	95	22.8	56.8	.521
May	293	7.9	68	.624
June	200	22.2	56	.514
July	242	24.6	62.9	.577
August	930	24.0	125	1.147
September	109	29.4	51.7	.474
October	59	24	37.3	.342
November (1-16)	30	21	23.8	.218
1912				
April (22-30)	48	30	36.1	.33
May	170	32	75.6	.69
June	312	18	56.8	.52
July	734	24	249.6	2.29
August	180	36	76	.70
September	125	33	62.5	.57
October	89	24	53.8	.49
November (1-15)	38	30	34.3	.31
1913				
April (21-30)	59.0	24.0	32.6	.300
May	289.0	22.0	96.6	.886
June	310.0	24.0	80.8	.741
July	117.0	16.0	42.1	.386
August	95.0	7.0	28.8	.264
September	54.0	9.0	16.4	.150
October	35.0	9.0	16.9	.155

Bow River—Hydro-Electric Plant at Horseshoe Fall

Bow River—Kananaskis Fall

DISCHARGE OF FISH CREEK, NEAR PRIDDIS, ALTA.—*Continued*

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1914				
April (7-30)	47.0	21.00	35.0	.321
May	55.0	15.20	28.0	.257
June	110.0	15.20	37.0	.340
July	81.0	1.70	17.3	.159
August	20.2	1.20	5.1	.047
September	5.9	1.40	3.5	.032
October	33.0	2.50	17.0	.156
1915				
March (15-31)	1,540	404	953	8.743
April	490	16	99	.908
May	952	22	214	1.963
June	7,020	58	547	5.018
July	2,760	216	711	6.523
August	774	59	190	1.743
September	332	67	140	1.284
October	223	65	122	1.119

Nose Creek

Nose creek rises in township 28, about eight miles west of the fifth meridian, and flows into the Bow river from the north at Calgary. Its course is almost due south and is paralleled by the Edmonton branch of the Canadian Pacific railway.

MONTHLY DISCHARGE OF NOSE CREEK, NEAR CALGARY, ALTA.
(Drainage area, 294 square miles)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1911				
April (24-30)	21.1	6.5	12.4	.042
May	85.3	6.5	20.6	.070
June	110.0	6.5	30.3	.103
July	17.4	5.7	8.7	.030
August	42.1	6.5	14.4	.049
September	17.4	7.9	9.8	.033
October	9.6	5.9	7.4	.025
November (1-15)	6.5	5.7	5.8	.020
1912				
March (26-31)	94	53	77.7	.264
April	77	6.5	29.8	.101
May	66	15.2	37.3	.127
June	75	7	17.5	.060
July	82	15.5	44.9	.153
August	82	12.3	27.6	.094
September	83	31	55.2	.188
October	52	17.4	32.1	.109
November (1-15)	28	8.7	17.5	.060

MONTHLY DISCHARGE OF NOSE CREEK, NEAR CALGARY, ALTA.
Continued

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1913				
April (10-30)	227	15.6	81.4	.277
May	177	15.6	56.3	.191
June	167	11.6	44.2	.150
July	135	14.9	38.3	.130
August	36	10.7	18.3	.062
September	29	10.4	15.0	.051
October	11.6	10.1	10.8	.037
1914				
May (7-31)	14.4	7.0	9.9	.031
June	48.0	7.0	15.5	.048
July	16.7	4.1	7.7	.024
August	7.0	3.2	4.4	.014
September	9.3	3.4	5.5	.017
October	15.5	5.7	10.3	.032
1915				
April	23	6	12	.040
May	166	7	34	.116
June	1,011	21	140	.476
July	1,225	23	312	1.060
August	1,935	90	344	1.170
September	235	112	137	.466
October	144	80	108	.367

Elbow River

The Elbow river forms one of the main tributaries of the Bow and enters it within the boundaries of the city of Calgary. It rises in the eastern ranges of the Rockies and flows eastward till it reaches a point due south of Calgary, thence northward to the Bow.

A reconnaissance survey of the Elbow river was recently made by the Water Power branch, and several schemes are being considered with a view to securing the most economical and efficient development. The cost of development, it is reported, would be comparatively high. One of the projects proposed would produce approximately 3,600 continuous electrical h.p. with an increase to 4,200 h.p. during part of the year. This proposition includes both a storage and a power dam, the location of the latter being at section 15, township 22, range VI, west of fifth meridian. A head of 225 feet would be available through a flume line, 1.75 miles long.

Another project would develop a head of 500 feet, bringing the water from the storage dam to the power-house by tunnel and pipe line.

A gauging station was established on this river at Calgary by the Irrigation branch of the Department of the Interior in 1908. The following is a summary of observations at this station:

MONTHLY DISCHARGE OF ELBOW RIVER, AT CALGARY, ALTA.
(Approximate drainage area, 482 square miles.)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1908				
May (8-31)	1,165	212	694.5	1.44
June	5,615	960	2,266	4.69
July	1,000	360	700.3	1.45
August	410	260	332.6	.690
September	310	260	280.8	.582
October	360	212	244.8	.508
November (1-12)	360	212	236.5	.490
1909				
May	2,757	220	968	2.01
June	3,320	717	1,377.2	2.86
July	2,282	502	929.9	1.93
August	695	271	430.6	.892
September	271	238	255.5	.530
October	240	226	231.4	.480
1910				
April	165	76	101	.209
May	602	156	308.5	.640
June	650	336	466	.967
July	387	204	282	.585
August	412	194	287.5	.596
September	657	237	421.9	.875
October	363	237	291.6	.605
November	323	90	205.5	.426
December	161	72	119	.247
1911				
January	73	45	62.2	.129
February	123	73	95.9	.199
March	255	86	141	.293
April	539	79	236	.490
May	1,063	190	407	.844
June	1,466	635	915	1.898
July	1,208	436	633	1.313
August	3,159	430	982	2.037
September	1,546	464	700	1.452
October	470	290	367	.761
November	377	75	212	.440
December	225	31	100	.207
1912				
January	139	34	106.3	.22
February	155	100	120.2	.25
March	300	65	129.4	.27
April	400	180	263	.54
May	590	255	461	.96
June	4,312	299	937	1.94
July	3,690	614	1,588.9	3.30
August	838	412	554.5	1.15
September	535	323	403.2	.84
October	426	281	332.2	.69
November	168	113	149.9	.31
December	191	48	117.7	.24

MONTHLY DISCHARGE OF ELBOW RIVER, AT CALGARY, ALTA.—*Continued*

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1913				
January	129	67	92	.192
February	138	114	126	.261
March	183	62	107	.222
April	1,205	136	406	.842
May	1,112	172	538	1.120
June	1,171	455	695	1.444
July	961	317	476	.988
August	1,367	348	559	1.160
September	461	245	320	.664
October	268	236	247	.512
November	268	198	230	.477
December	200	69	138	.286
1914				
January	159	75	115	.24
February	127	92	110	.23
March	130	109	113	.23
April	372	145	255	.53
May	576	232	396	.82
June	1,020	412	691	1.43
July	796	252	453	.94
August	414	180	255	.53
September	240	168	199	.41
October	472	236	336	.70
November	234	130	174	.36
December	158	100	121	.25
1915				
January	148	99	126	.266
February	117	99	105	.222
March	401	97	157	.331
April	252	192	218	.460
May	2,005	200	1,198	2.53
June	8,427	1,163	2,127	4.49
July	4,033	1,203	1,930	4.07
August	2,035	447	907	1.91
September	947	528	656	1.38
October	723	424	558	1.18
November	424	234	299	.631
December	229	65	186	.392

CHAPTER XI

Bow River above Calgary*

Conservation of the waters of the Bow river is of the utmost moment, for upon it directly depends the agricultural and industrial prosperity of a very large area of southern Alberta. Rising in the high and remote regions of the Rocky Mountains National Park, and, with numerous tributaries, furnishing the most interesting and attractive feature of its world-famed scenery, the river emerges from the park only to be harnessed to supply energy for transmission to the city of Calgary for municipal purposes, street lighting, tramways, and for general commercial and industrial use. After furnishing the hydro-electric energy, the same waters have, by irrigation, converted thousands of acres of otherwise useless land into the most fertile tracts within the province.

Dual Use of Water

At first consideration it would appear that the two important uses of this water, for irrigation and for power, would result in a serious conflict of interest. Fortunately, however, irrigation requirements occur during the high-water stages of the river. Storage reservoirs on its upper waters would also make it possible to conserve enough of the flood flow, not required for irrigation, to compensate for the low water during the winter months, when otherwise the volume would not be sufficient for power purposes.

The present use and distribution and the future conservation of the water resources of the Bow River basin, constitute one of the most important problems before the Department of the Interior. In some of its phases this problem has already been solved, while in others it awaits solution, although a beginning has been made and the lines of practicable progress have been fairly well marked out.

*Note.—The storage and power possibilities of this river above Calgary have been investigated by the Water Power branch of the Department of the Interior, and a detailed report, made by M. C. Hendry, has been published as *Water Resources Paper No. 2.* The greater portion of this chapter, relating to the Bow river proper, is a brief summary of the above publication, prepared by Mr. J. B. Challies, superintendent of the Water Power branch, for insertion as a part of this report. The tables of discharges for stations on the Bow river, situated above and below Calgary, are grouped together in chapter X.

General Description of River

The Bow is a typical mountain river, rising in the eastern slope of the Rocky Mountain system, west of the city of Calgary, Alberta. It drains an area of 3,138 square miles. The mountain portion of the basin—the portion above the Kananaskis fall—includes an area of 1,710 square miles. Fortunately, the mountain area is in the Rocky Mountains National Park, and enjoys all the advantages of park administration. The river has a very steep slope, and in several places falls occur, caused by outcropping ledges of sandstone. Bow lake, in the headwaters, is at an elevation of about 6,620 feet above sea level. Thence to Kananaskis fall, at the confluence of the Kananaskis river, a distance of 90 miles, the descent is approximately 2,250 feet. Between Kananaskis fall and Calgary, a distance of 55 miles, it descends an additional 775 feet. Its flow is typical of all mountain streams, subject to sudden variation, and greatly influenced by conditions of temperature. During the winter it is greatly reduced, but in June and July, rains and the melting of the glaciers cause floods, and the variation between high and low water is very great. While no direct gaugings of extreme flood discharges are available, it has been computed, from levels taken by the Canadian Pacific Railway Company at Bow bridge and Kananaskis bridge, that at Horseshoe fall a flood of 45,000 c.f.s. has occurred. A low water discharge of less than 600 c.f.s. has been recorded at the same point. Records of the discharge at various points have been kept more or less continuously since 1909.

Water-power Producing Section

What may be termed the power-producing section of the river is a stretch about 30 miles long, within easy transmission radius of the largest power market of the district, the city of Calgary. The growth of this city has been phenomenal. As the city controls its public utilities, including street railway, water-works, electric light, etc., it is in the market for power in rapidly increasing amounts. There are, also, other large users of power, including the Canadian Pacific railway.

Power for Municipal Lighting

The first hydro-electric development on the Bow river was that of the Eau Claire Lumber Company, situated within the city limits of Calgary. This development utilizes about 12 feet of the natural fall of the river, by means of a diverting dam (pile and timber construction) and a canal. The present installation is for 600 horse-power, but it is understood that additional installation is proposed.

Calgary Power Co., Ltd.

A growing demand for hydro-electric power at Calgary resulted in the Calgary Power Co., Ltd., constructing a modern 19,500 horse-power hydro-electric plant at Horseshoe fall, about 48 miles from the city (see plate facing

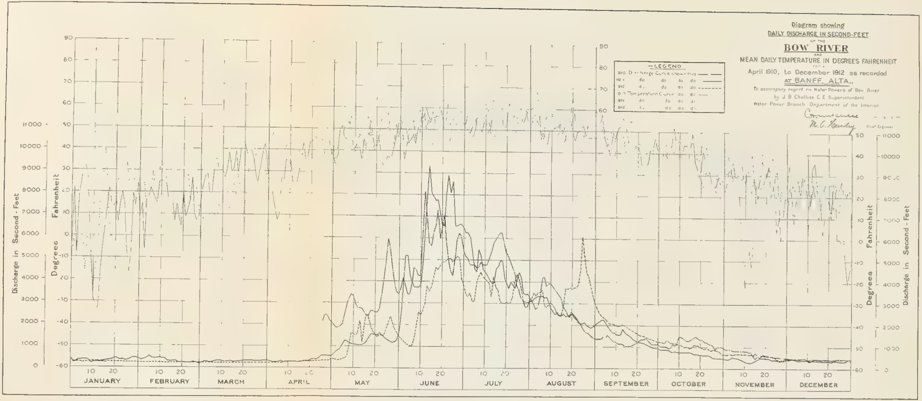
Diagram showing
DAILY DISCHARGE IN SECOND-FEET
BOW RIVER
AND
MEAN DAILY TEMPERATURE IN DEGREES FAHRENHEIT
April 1910, to December 1912 as recorded
AT BANFF, ALTA.,
To accompany report on Water Powers of Bow River
by J. B. Challies C.E. Superintendent
Water Power Branch Department of the Interior
M. C. Hendry
LEGEND
Discharge in Second - Feet
Degrees Fahrenheit
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

page 208). Owing to variation in flow, the output is not continuous. This development was commenced in 1909 and completed on the assumption that the minimum flow of the river was about 1,000 c.f.s. Unfortunately, in the early stages of operation it was discovered that the minimum flow was so much less than supposed that the company was, early in 1911, confronted with the immediate necessity of either constructing a steam auxiliary plant at Calgary, or of undertaking storage works at the most favourable point on the upper waters of the Bow river.

Storage Works for Winter Flow

In March, 1912, construction was commenced on a storage dam at the outlet of lake Minnewanka, in the Rocky Mountains National Park. It was completed in time to impound the flood waters of the summer of 1912, and make them available for the winter flow of 1912-13. By the construction of this dam, about 58,000 acre-feet of water can be stored, of which 44,000 acre-feet are guaranteed to the power company. In constructing this dam provision has been made for all necessary permanent works for an intake to a future power project on the Cascade river, which will be capable of developing about 900 continuous electrical horse-power, to be used for park purposes within the Rocky Mountains National Park.

Kananaskis Fall Plant

The Calgary Power Co. has also constructed an additional plant (see plate facing page 210) at Kananaskis fall, about 1½ miles west of its present plant at Horseshoe fall, where, with a head of 70 feet, machinery capable of producing 11,000 horse-power has been installed. The company's two plants are being operated together, and the power is mainly transmitted for use in and near the city of Calgary. With these two plants in operation, and with the present storage at Minnewanka lake, a continuous output of 11,600 wheel horse-power can probably be depended upon.*

Power and Storage Investigations

The rapidly increasing demand for power from the Bow river, and the necessity for providing adequate storage facilities for existing and contemplated plants on the river, rendered necessary immediate and vigorous action by the Water Power branch of the Department of the Interior, to investigate the power and regulation facilities of the river, and at the same time, to formulate a policy providing for the maximum advantageous utilization of the resources of the river in the best interest of present and prospective users, for both power and irrigation purposes. Accordingly, Mr. J. B. Challies commenced, in 1911, a thorough investigation of the Bow river, and its tributaries west of Calgary. The field

*A more detailed description of these plants is appended hereto, p. 209.

work was carried on under the direction of M. C. Hendry, with the general advice and assistance of Mr. C. H. Mitchell, of the consulting engineering firm of C. H. & P. H. Mitchell, Toronto, one of the board of consulting engineers to the Water Power branch in connection with water-power matters in Western Canada. Mr. Mitchell also collaborated with Mr. Hendry in the preparation of his report, published as *Water Resources Paper No. 2.*

Preliminary Steps

A thorough reconnaissance of the whole Bow River basin was made, with subsequent surveys of all possible power sites and storage basins. Owing to the lack of run-off data at important points, both on the Bow river and its tributaries, additional gauging stations were established by the hydrographic engineers of the Interior Department. Most of the previous work of stream gauging in this district, while excellent, had been carried on only during open water season, and little information was available as to the flow during the winter months. The work was carried on by Mr. Hendry during the summer of 1911 and summer and winter of 1912. In the two summer seasons the following was accomplished:

Reconnaissance of Bow and Tributaries

Reconnaissance was made of Kananaskis river, Kananaskis lakes, Spray river and tributaries and Spray lakes, Bow lake, Hector lake, Pipestone creek, Baker lake, Ptarmigan lake, Redoubt lake, Johnston creek, Redearth creek, Brewster creek, Forty-mile creek, and Ghost river.

A thorough reconnaissance, preliminary to surveys, was made by both Mr. Hendry and Mr. Mitchell, of the power-producing portion of the Bow river between Kananaskis fall and Radnor. The creeks and lakes examined on these trips were either eliminated as being unsuitable for power or storage purposes, or accepted as feasible, and some general scheme for development settled on. In the latter case a field party was then assigned to carry out the investigations in detail.

Topographical Surveys

During the summer of 1911 and 1912, detailed topographical surveys were made of approximately 30 miles of the Bow river, from the Canadian Pacific Railway bridge above Kananaskis fall, down as far as Radnor, particular attention being given to the several possible power sites. Topographical surveys were also made of Bow lake, lake Minnewanka, and the basin of the Spray lakes, with a view to the creation of storage.

The profile of the Bow river above Calgary shows the results of these surveys. Briefly, there are six power sites on the power-producing stretch of the Bow river, as follows:—

1. Kananaskis Fall site, developed.
2. Horseshoe Fall site, developed.
3. Bow Fort site, undeveloped.

AT HORSESHOE FALLS

Diagram of Discharge in Acre-ft. from Jan. 1909 to Feb. 1913

Compiled from Measurements made at MORLEY BRIDGE AND HORSESHOE FALLS
Showing conditions under a continuous flow of 1500 Sec. ft.

To accompany report on Water Powers of Bow River
by J. B. Challies, C. E. Superintendent.
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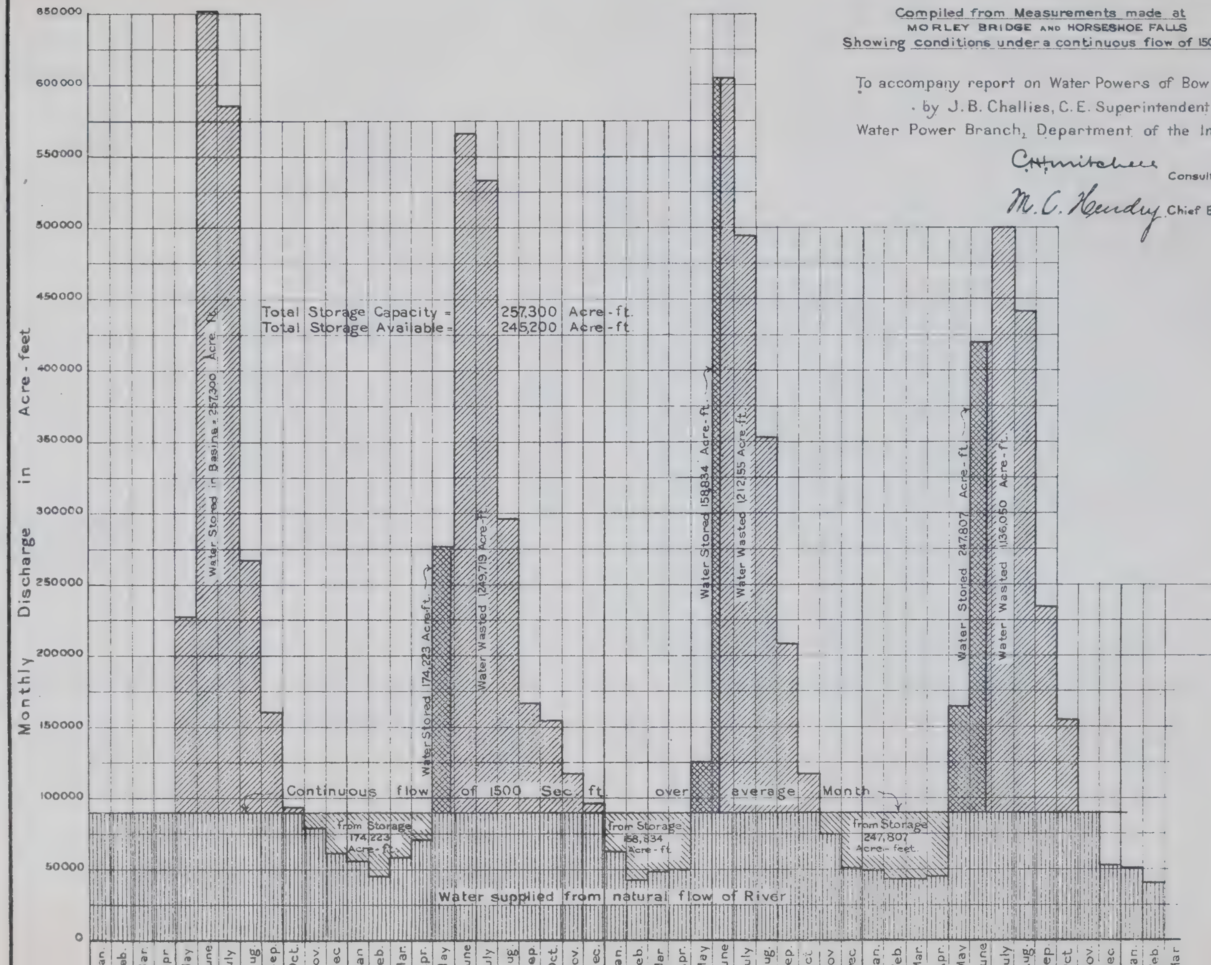


4. Mission site, undeveloped.
5. Ghost site, undeveloped.
6. Radnor site, undeveloped.

Two other developments in this basin have been proven feasible, one of about 900 horse-power capacity on the Cascade river, immediately below the outlet of lake Minnewanka, where the Calgary Power Co. has constructed a storage dam; the other on the Kananaskis river, just above the Canadian Pacific bridge, where a combined storage and power development has been proposed by the same company.

Bow Fall as a Scenic Feature

The famous Bow fall, on the Bow river, near the Canadian Pacific Railway Company's hotel at Banff, has been considered to have a far greater potential value from an æsthetic standpoint than from any possible use for power development purposes. For this reason no attempt has been made to consider it from a utilitarian viewpoint.

Storage Possibilities

The storage possibilities of the basin are extensive and important, although the question of flow during winter conditions from the possible storage reservoirs must be further considered before any comprehensive construction scheme is finally determined. Results of the surveys are briefly summarized in the following tables:

STORAGE BASINS

Basin	Capacity
Bow lake	27,400 acre-ft.
Spray lake	171,000 " "
Lake Minnewanka	44,700 " "
Lake Minnewanka auxiliary (created)	14,200 " "
Total above Calgary on Bow river	243,100 " "
Total above Calgary with auxiliary	257,300 " "
Elbow river	23,000 " "
Total above Calgary, including auxiliary at Minnewanka	280,300 " "

POWER SITES

Site	Pondage above dam in acres	Head in feet
Bow river—		
1. Kananaskis fall	122.25	70 operating
2. Horseshoe fall	98.47	70 operating
3. Bow Fort	205.19	66
4. Mission	353.09	47
5. Ghost	786.10	50
6. Radnor	241.50	44
Cascade river—		
At Minnewanka dam	4,000	64
Kananaskis river—		
Above C. P. Ry. bridge	620	45

In addition, it is probably possible to develop power at several points on the Spray river below the proposed storage dam, but no detailed investigation has been made.

Benefits of Storage

All possible storage on the Bow river above Calgary is available for the whole power section of the river between Kananaskis fall and Radnor. The mean flow for the low winter months, as recorded at Horseshoe fall, has been found to be as low as 720 c.f.s., and the minimum flow as low as 600 c.f.s. By means of the storage that has been and that may be created, it is anticipated that the mean flow can be raised to at least 1,500 c.f.s. Below the mouth of the Ghost this would be increased to 1,600 c.f.s.

The effect of storage upon the power output of the river, over that due to the natural flow, is shown in the following tables:

SHOWING EFFECT OF REGULATION AT EACH POWER SITE ON BOW RIVER

Power site	Continuous wheel h.p.	
	Natural flow	Regulated flow
Kananaskis fall (developed)	3,820	9,545
Horseshoe fall (developed)	3,820	9,545
Bow Fort	3,600	9,000
Mission	2,565	6,410
Ghost	3,180	7,275
Radnor	2,800	6,400
Total	19,785	48,175

Department power site at Minnewanka dam, Cascade river ...... 1,165 w.h.p.
Grand total of power capacity of river fully regulated ....49,340 w.h.p.
Giving an increased continuous output of ....29,555 w.h.p.

A tabulated summary is shown of the effects of storage upon the developed and undeveloped water-power sites within the power producing stretch of the Bow river. This table is compiled from diagrams and shows the effect of storage upon the river for different assumptions.

SUMMARY OF EFFECT OF STORAGE IN THE BOW RIVER BASIN UPON THE DEVELOPED AND UNDEVELOPED WATER-POWERS

Proposed site or plant	Natural Flow								Regulated Flow						
	Elevation of crest of dam†	Working head, in feet	Rated h.p. of turbines installed or proposed	Minimum mean monthly flow in c.f.s.	Available h.p. with flow as in Col. 5	H.P. years available in aver. year with wheel capacity as in Col. 4	Possible turbine output, 24 hr. power, 60 per cent of time	H.P. years available from water using wheel capacity as in Col. 8	Minimum regulated flow in c.f.s.	H.P. years added within capacity of proposed wheels	H.P. years available from regulated flow as in Col. 10	Possible turbine output, 24 hr. power, 60 per cent of time	H.P. years available from water with turbine capacity as in Col. 13	Continuous h.p. available with flow as in Col. 10	H.P. years added from storage with flow as in Col. 10
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Developed—															
1. Kananaskis	4,155	70	11,600	720	4,580	8,887	7,400	6,643	1,500	2,138	7,847	11,110	10,754	9,545	1,698
2. Horseshoe fall ...	4,082	70	19,500	720	4,580	12,087	7,400	6,643	1,500	2,171	7,847	11,110	10,754	9,545	1,698
Undeveloped—															
3. Bow Fort	4,010	66	*13,200	720	4,320	9,421	6,950	6,262	1,500	2,053	7,407	10,420	10,089	9,000	1,593
4. Mission	3,865	47	*10,500	720	3,760	7,161	4,930	4,450	1,500	1,493	5,277	7,510	7,260	6,410	1,132
5. Ghost	3,812.5	50	*10,500	820	3,730	7,669	5,710	5,194	1,600	1,544	6,085	8,420	8,150	7,275	1,188
6. Radnor	3,760	44	*10,500	820	3,280	7,207	5,345	4,589	1,600	1,375	5,345	7,450	7,210	6,400	1,055

* These capacities provide for an over development of from 44 to 64 per cent and are taken arbitrarily; they provide also for considerable load fluctuations.

† To reduce these elevations to above mean sea level approxim ately 43 feet should be added.

The lack of continuous records of runoff over any considerable period renders positive conclusions impossible, but it is considered that these discharges recorded under low-water conditions are approximately correct. After careful investigation and a study of the runoff and meteorological data available, together with a knowledge of the physical conditions obtaining throughout the year, it has been found that the mean monthly flow at Horseshoe fall during the period recorded does not fall below 720 c.f.s. During short periods, perhaps a single day, the flow has dropped below 600 c.f.s., but the mean monthly flow, upon which the storage scheme must be based, is approximately 720 c.f.s. The lowest mean monthly flow for the period 1909-1912 was 833 c.f.s., and occurred in the low-water season of 1911-12.

The benefits from storage have been worked out upon the basis of mean monthly flow, and a fair allowance has been made for loss due to evaporation and wastage between the point of storage and the point of utilization. The results of these studies show that, at the lowest season, a discharge of 1,500 second-feet can be secured.

Available Storage

In preparing the following flow tables, the effect to be obtained from storage was taken as that due to the discharge of 160,000 acre-feet from the proposed Spray basin, of 27,000 acre-feet from the proposed Bow Lake basin, and of 44,000 acre-feet from Lake Minnewanka basin (12 feet draw down of lake). In addition there can be made available at Minnewanka a further storage of 14,200 acre-feet (16 feet draw down). The flow tables give the quantity in cubic feet per second and acre-feet required to raise the mean monthly flow from that recorded to discharges ranging from 800 c.f.s. to 1,500 c.f.s. At the foot of each column the mean flow for the low water period is given, together with the total acre-feet necessary to produce the given discharge for the period. Below the table is given in concise form the effect of the flow from each storage basin upon the discharge, and, finally, the combined effect of all the storage basins upon the flow.

For the low-water period 1909-10, the mean discharge for the period for an average month is 1,025 c.f.s. With this as a basis, the table shows that, providing for a flow of 1,500 c.f.s. over the low water period, November to April, inclusive, there will be a surplus of 60,938 acre-feet, without making use of the extra storage available in Minnewanka, or, including 14,200 acre-feet auxiliary storage, a total of 75,138 acre-feet, sufficient to provide for a flow of 1,705 c.f.s. over the whole period.

For the low-water period 1910-11, the mean discharge is 1,124 c.f.s. over the whole period. As before, providing for a continuous

flow of 1,500 c.f.s. over this period, there is a surplus (omitting the auxiliary storage) of 75,545 acre-feet, or, including the 14,200 acre-feet auxiliary storage, a total of 89,745 acre-feet, which would give a continuous flow from October to April of 1,804 c.f.s.

During the period 1911-12, the mean flow was only 833 c.f.s., and, to secure a flow of 1,500 c.f.s., the entire storage capacity, including the auxiliary 14,200 acre-feet, a total of 245,200 acre-feet, would be required.

From these figures it seems assured that a flow of 1,500 second-feet can be maintained. During seasons of unusually low water this may possibly not be realized, and records over a longer period would give more weight to the conclusions drawn, but, in the absence of more definite information, this flow has been accepted as reasonably certain, and the developments between Horseshoe fall and Ghost river have been based upon this assumption.

The precipitation during the low-water season, October 1 to March 31, 1911-12, was less than for any other season during the past eight years, and the total precipitation for the water year 1911-12 was just 0.38 inch higher than the mean precipitation over a period of 16 years. In view of this, the foregoing assumption regarding discharge appears justified.

Effect of Storage on Discharge

Between Kananaskis fall and the mouth of the Ghost river, using a storage capacity of 243,100 acre-feet, and an auxiliary storage at lake Minnewanka of 14,200 acre-feet, a flow of 1,500 second-feet may be maintained during the low-water period of any year; during years of ordinary precipitation, this flow may be as much as 1,700 c.f.s.

Below the mouth of the Ghost river, the regulated flow may be increased by at least 100 c.f.s., or, from the Ghost river to Radnor, a continuous flow of 1,600 c.f.s. would be available; during some seasons it might reach 1,800 c.f.s.

Complete data are not available for the discharge of creeks tributary to the Bow between Radnor and Calgary, but below Calgary, and including the regulated flow of the Elbow, a flow of nearly 2,000 c.f.s. may be expected during the low water period.

A profile of the power producing stretch of the river is shown on plate facing page 202. This plate demonstrates the inter-relation of the head and tail waters of the different plants, and of the proposed concentrations.

Estimates of Cost

Estimates of cost have been prepared providing for a complete development of the three proposed storage basins, including that already built at the outlet of lake Minnewanka, and for four additional power plants on the power

FLOW FROM STORAGE, SEASON 1909-1910

Month	Mean nonthly flow c.f.s.	To raise natural flow to													
		800 sec. ft.		850 sec. ft.		900 sec. ft.		950 sec. ft.		1,000 sec. ft.		1,200 sec. ft.		1,500 sec. ft.	
		c.f.s.	Ac. ft.	c.f.s.	Ac. ft.	c.f.s.	Ac. ft.	c.f.s.	Ac. ft.	c.f.s.	Ac. ft.	c.f.s.	Ac. ft.	c.f.s.	Ac. ft.
1909															
November .	1,320													180	10,710.7
December .	990									10	614.87	210	12,495.8	510	31,358.7
1910															
January ..	910							40	2,459.5	90	5,533.8	290	17,831.4	590	36,277.7
February .	790	10	555.37	60	3,332.2	110	6,109 1	160	8,885.9	210	11,662.8	410	22,770.1	710	39,431.4
March	940							10	614.87	60	3,689.2	260	15,986.8	560	34,433.06
April	1,200													300	17,851.2
Mean flow	1,025	Total	555.37		3,332.2		6,109.1		11,960.27		21,500.67		69,084.1		170,062.76

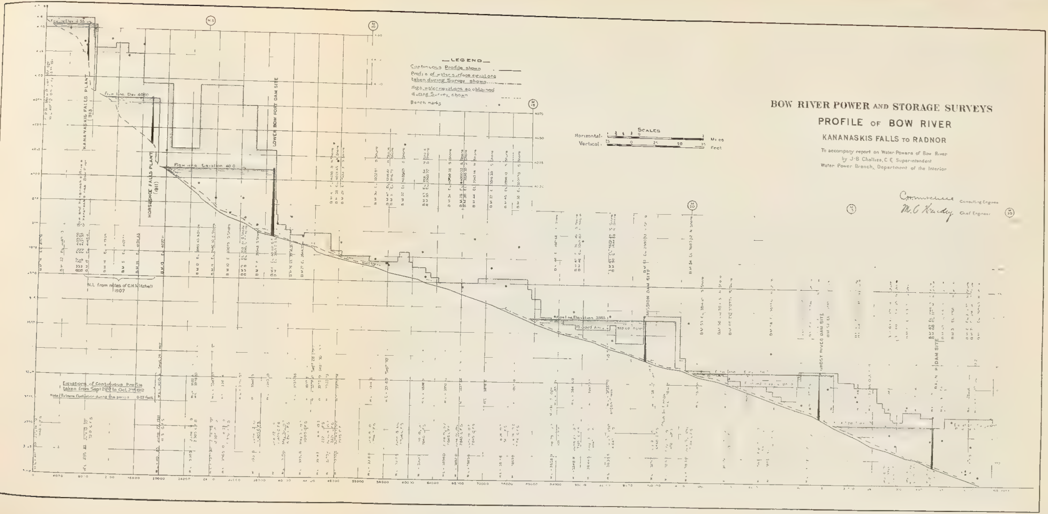
Minnewanka storage = 44,000 acre-feet
Bow Lake " = 27,000 " "
Spray Lake " = 160,000 " "

Total 231,000
Auxiliary to Minnewanka 14,200 " "

Grand total = 245,200 " " (Max. storage)
Storage required during low water period of 1909-1910 for continuous flow of 1,500 sec. ft. is 170,062.7 acre feet
Surplus water in storage is
(231,000 - 170,062=60,938 acre feet
or (245,200 - 170,062=75,138 " "

Mean flow for low water period 1909 and 1910 is	1,025 sec. ft.
The regulated flow with Minnewanka storage ...	1,148 " "
and auxiliary	1,167 " "
Bow Lake storage	1,100 " "
Spray Lake storage	1 468 " "
Bow and Minnewanka storage combined	1,223 " "
Spray and Minnewanka storage combined	1,591 " "
Spray Lake and Bow Lake storage combined ..	1,543 " "
The regulated flow with maximum storage Spray, Bow, Minnewanka and auxiliary	1,705 " "

Maximum storage for 1909-10 for a continuous flow of 1,500 sec. ft. gives a surplus flow of 205 sec. ft.


BOW RIVER POWER AND STORAGE SURVEYS
PROFILE OF BOW RIVER
KANANASKIS FALLS TO RADNOR
To accompany report on Water Powers of Bow River
by J. B. Challies, C. E. Superintendent
Water Power Branch, Department of the Interior
Consulting Engineer
Chief Engineer
LEGEND
Continuous Profile shown
Profile of water surface elevations taken during Survey shown
High water elevations as obtained during Survey shown
Bench marks
SCALES
Horizontal
Miles
Vertical
Feet
KANANASKIS FALLS PLANT (1913)
HORSESHOE FALLS PLANT (1911)
LOWER BOW FORT DAM SITE
MISSION DAM SITE
GHOST RIVER DAM SITE
Flow line Elev. 4080
Flow line Elevation 4010
Flow line Elevation 3885
Flooded Area
W. L. from notes of C. H. Mitchell 1907
Elevations of Continuous Profile taken from Sept. 28th to Oct. 2nd 1912

FLOW FROM STORAGE, SEASON 1910-1911

Month	Mean monthly flow	To raise natural flow to													
		800 sec. ft.		850 sec. ft.		900 sec. ft.		950 sec. ft.		1,000 sec. ft.		1,200 sec. ft.		1,500 sec. ft.	
	c.f.s.	c.f.s.	Ac. ft.	c.f.s	Ac. ft.	c.f.s.	Ac. ft.	c.f.s.	Ac. ft.	c.f.s.	Ac. ft.	c.f.s	Ac. ft.	c.f.s.	Ac. ft.
1910															
November .	1,866														
December .	1,483													17	1,045.3
1911															
January ...	1,027											173	10,637.35	473	29,084.6
February ..	745	55	3,054.54	105	5,831.40	155	8,608.25	205	11,385.10	255	14,161.96	455	25,269.33	755	41,930.56
March	795	5	307.43	55	3,381.81	105	6,456.19	155	9,530.57	205	12,604.92	405	24,902.47	705	43,348.75
April	827			23	1,368.50	73	4,343.8	123	7,319.0	173	10,294.2	373	22,195.04	673	40,046.3
Mean flow	1,124	Total	3,361.97		10,581.76		19,407.24		28,234.67		37,061.0		83,004.2		155,455.5

Minnewanka storage = 44,000 acre-feet
Bow Lake storage = 27,000 " "
Spray Lake storage = 160,000 " "

Total = 231,000 " "
Auxiliary to Minnewanka = 14,200 " "

Grand total = 245,200 " " (Max. storage)

Storage required during low water period of 1910 and 1911 for a continuous flow of 1,500 sec. ft. is ....155,455 acre feet
Surplus water in storage is
(231,000 - 155,455= .... 75,545 " "
or (245,200 - 155,455= .... 89,745 " "

Mean flow for low water period 1910 and 1911 is...1,124 sec. ft.
The regulated flow with Minnewanka storage is ....1,247 " "
and auxiliary storage is ....1,286 " "
The regulated flow with Bow Lake storage ....1,199 " "
The regulated flow with Spray Lake storage ....1,576 " "
The regulated flow with Bow and Minnewanka storage combined ....1,322 " "
The regulated flow with Spray Lake and Minnewanka storage combined ....1,690 " "
The regulated flow with Spray lake, Bow lake and Minnewanka combined ....1,765 " "
The regulated flow with Spray lake and Bow lake combined ....1,642 " "
The regulated flow with (max. storage) Spray, Bow, Minnewanka and auxiliary combined ....1,804 " "

Maximum storage for 1910 and 1911 for a continuous flow of 1,500 sec. ft. gives a surplus flow of 304 sec. ft. over low water period.

FLOW FROM STORAGE, SEASON 1911-1912

Month	Mean monthly flow	To raise natural flow to													
		800 sec. ft.		850 sec. ft.		900 sec. ft.		950 sec. ft.		1,000 sec. ft.		1,200 sec. ft.		1,500 sec. ft.	
	c.f.s.	c.f.s.	Ac. ft.	c.f.s.	Ac. ft.	c.f.s.	Ac. ft.	c.f.s.	Ac. ft.	c.f.s.	Ac. ft.	c.f.s.	Ac. ft.	c.f.s.	Ac. ft.
1911															
November ...	1,056											144	8,568.6	444	26,419.8
December ...	836			14	860.8	64	3,935.2	114	7,009.5	164	10,083.9	364	22,381.4	664	40,826.7
1912															
January	786	14	860.8	64	3,935.2	114	7,009.5	164	10,083.9	214	13,158.3	414	25,455.8	714	43,902.1
February	766	34	1,955.7	84	4,831.7	134	7,707.7	184	10,583.7	234	13,459.7	434	24,936.7	734	42,219.7
March	720	80	4,919.0	130	7,993.4	180	11,067.7	230	14,142.2	280	17,216.5	480	29,514.0	780	47,960.3
April	835			15	892.5	65	3,867.7	115	6,843.0	165	9,817.6	365	21,719.0	665	39,570.2
Mean flow ..	833	Total	7,735.5		18,513.6		33,587.8		48,662.3		63,736.0		132,574.5		240,898.8

Minnewanka storage	= 44,000	acre-feet
Bow Lake storage	= 27 000	" "
Spray Lake storage	= 160,000	" "
(1) Total	= 231,000	" "
Auxiliary to Minnewanka	= 14,200	" "
(2) Grand total	= 245,200	" "

(1) Would give a regulated flow over low water period 1911 and 1912=1,473.0 sec. ft.

(2) Would give a regulated flow over low water period 1911 and 1912=1,512.0 sec. ft.

Mean flow low water period 1911 and 1912 is	833	sec. ft.
The regulated flow with Minnewanka storage is (833+122)	955	" "
The regulated flow with auxiliary storage from Minnewanka is (955+39)	994	" "
The regulated flow with Bow Lake storage (833+75)	908	" "
The regulated flow with Spray Lake storage (833+443)	1,276	" "
The regulated flow with Bow Lake added to Minnewanka	1,030	" "
with auxiliary	1,069	" "
The regulated flow with Spray and Bow Lakes combined	1,351	" "
The regulated flow with Spray added to Bow, Minnewanka and auxiliary (max. storage)	1,512	" "
The regulated flow with Spray Lake and Minnewanka combined	1,398	" "
The max. storage for 1911 and 1912 will give a continuous flow over the low water period of......	1,512	" "

producing stretch of the river, together with duplicate transmission lines sufficient to carry the total output from the four additional plants to Calgary, as well as adequate receiving equipment at Calgary.

These estimates are, of course, only preliminary. They are merely for the purpose of obtaining a comparison of costs, and arriving at a reasonable conclusion as to the commercial possibilities of the whole conservation project, including the construction of the various storage works, and of the four additional power plants. They have been conservatively computed, and are considered ample to cover all contingencies, based upon existing labour and market conditions. The results of these estimates of cost are summarized in the following tables:

STORAGE DEVELOPMENT

Site	Capacity acre-feet	Estimated cost	Cost per acre-foot
Bow lake	27,400	$105,000	$3.83
Spray lake	171,000	514,000	3.00
Minnewanka	44,700	145,000	3.24
	58,900	145,000	2.46
Elbow river	23,000	200,000	8.70

POWER DEVELOPMENTS

Site	Head in feet	Continuous output w.h.p.	Estimated cost of plant including cost of storage	Estimated cost of power per k.w.hr.* in cents
Bow Fort	66	9,000	$924,970.00	0.49
Mission	47	6,410	851,100.00	0.60
Ghost	50	7,275	892,500.00	0.57
Radnor	44	6,400	807,460.00	0.59

IRRIGATION

The effect of the creation of storage upon irrigation requirements, is a question which must be considered with the effect on the power interests.

Calgary lies on the western and Regina on the eastern limit of a dry belt, in which the soil is, for the greater part, very fertile. Irrigation has been carried on in this district. The first project was constructed on Fish creek in 1879; but, it was not until 1893, that works were undertaken on an extensive scale.

* Estimated cost of power per k.w. hour, delivered in Calgary, on 50 per cent load factor basis, including storage, transmission lines, etc.

NOTE.—With reference to the foregoing, it may be of interest to note that in April, 1913, a comprehensive report was made for the city of Calgary wherein it was shown that electric power generated by a steam coal-fired plant, and sold on the basis of a 50 per cent load factor, would cost, delivered at generator terminals without transformation or transmission, from 0.85 cent down to 0.74 cent per k.w. hour, as the size of the plant increased from 5,000 k.w. to 45,000 k.w. capacity.

Numerous Irrigation Propositions

Of the first undertakings, the two largest were those of the Calgary Hydraulic Company, with headworks on the Elbow river west of Calgary, and the Calgary Irrigation Company, whose headworks were also on the Elbow. By the end of 1894 there were 70 systems of various sizes in operation.

Irrigation undertakings increased until, in 1902, the number of ditches in operation was 169, capable of irrigating 614,684 acres. Recently some of the projects have been abandoned, among others that of the Calgary Hydraulic Company.

About 1905, the Canadian Pacific Railway Company became an active advocate of irrigation, and instituted the largest and most comprehensive reclamation undertaking in the Canadian West. A main channel, with headworks just below the junction of the Bow and Elbow rivers, carries water to irrigate land to the east of Calgary. The principal undertaking is farther east, where the company has recently constructed the Bassano dam to serve 513,000 acres of irrigable land.

Relation of Power and Irrigation Requirements

It is well to recognize that the agricultural industry, with its accompanying irrigation requirements, is pre-eminent in this locality, and as regards the use of water, must take precedence of all power requirements.

When this investigation of the Bow river water supply was first undertaken, there was some apprehension respecting a possible conflict of interests in the adjustment of the water supply. As the investigations progressed, and broadened, however, it soon became apparent that instead of any interference, there was, on the contrary, rather a co-operative effect. On the broad principle that any storage project will equally assist both power production and irrigation, in supplying ample water for their requirements, it is obvious that there can be no conflict of rights if the river discharge is equably controlled so as to be uniform during the spring and autumn.

Irrigation at Favourable Water Seasons

Fortunately, water for irrigation is required only during high and normal water stages of the river, commencing not earlier than April 7, and extending to not later than September 30. During these summer months, at least three have flood discharge on this river, while the other two, viz., May and September, have discharges larger than the proposed new regulated flow of 1,500 second-feet at, say, Morley. The withdrawal of water by storage on the high summer flood will not interfere with efficient irrigation; on the contrary, provision is made for the future, because such a large supply cannot be maintained throughout the entire irrigable season; the month of April is much improved by storage, while September remains as before.

Under any circumstances, the requirements of irrigation should be kept clearly in mind, and, in the face of a threatened shortage, its reasonable demands must be given precedence.

With the limited space available, it has been impossible to discuss pertinent questions of cost, runoff, precipitation, temperature, evaporation, ice conditions, storage manipulation, and geology. All such, and other allied questions, have been exhaustively treated by Mr. Hendry, in *Water Resources Paper No. 2.*

Recommendations of Consulting Engineer

Mr. C. H. Mitchell, in submitting his final recommendations to the Department of the Interior, following the completion of Mr. Hendry's surveys, says:

> *General.*—If the country in the foothills east of the Rockies, and within transmission radius of the Bow river, is to be encouraged as an industrial region, the utilization of its natural resources is an economic necessity, and the utmost development of the water power of the Bow river is a logical outcome. In this region there are already rapidly growing industrial communities, and their steady growth is dependent on probably no more important factor than an ample supply of power.
>
> The Bow river is peculiar, in that, in its natural condition, its summer flood discharge is upwards of seventy times its low water winter discharge, a condition which obviously renders its use, in its present state, unsuitable, inefficient, and commercially unfeasible for power purposes.
>
> The investigations which have been carried on during the past two years, the results of which have been embodied in the general report of Mr. Hendry, and in which I have collaborated, indicate that, if the Bow river is to be an efficient commercial source of power, and at the same time to afford an ample water supply for power and irrigation purposes, it is absolutely necessary that the river be regulated and controlled, so as to ensure a fixed and usable supply of water continuously throughout the year.
>
> *Conditions to be Met.*—If the improvement of Bow river is undertaken for the advantage of the power and irrigation industries, it is obvious that it should be done by, and remain under the control of, the Government, because of the many conflicting interests involved. In addition to the irrigation interests, there are, or are likely to be, several power companies requiring water in some degree of uniformity throughout the year. Such being the case, it is evident that, once the storage system is constructed, its satisfactory operation can be secured only through the medium of some central official body, exercising an absolute control over the water supply, so as to obtain the greatest advantage and efficiency to the largest proportion of public users. All users must be made parties to the arrangement to make it completely co-operative.

Policy to be Framed.—If this water supply project is undertaken as a work of public benefit by the Dominion Government, it would naturally be the function of the Water Power branch of the Department of the Interior to carry it out, and subsequently administer its operation.

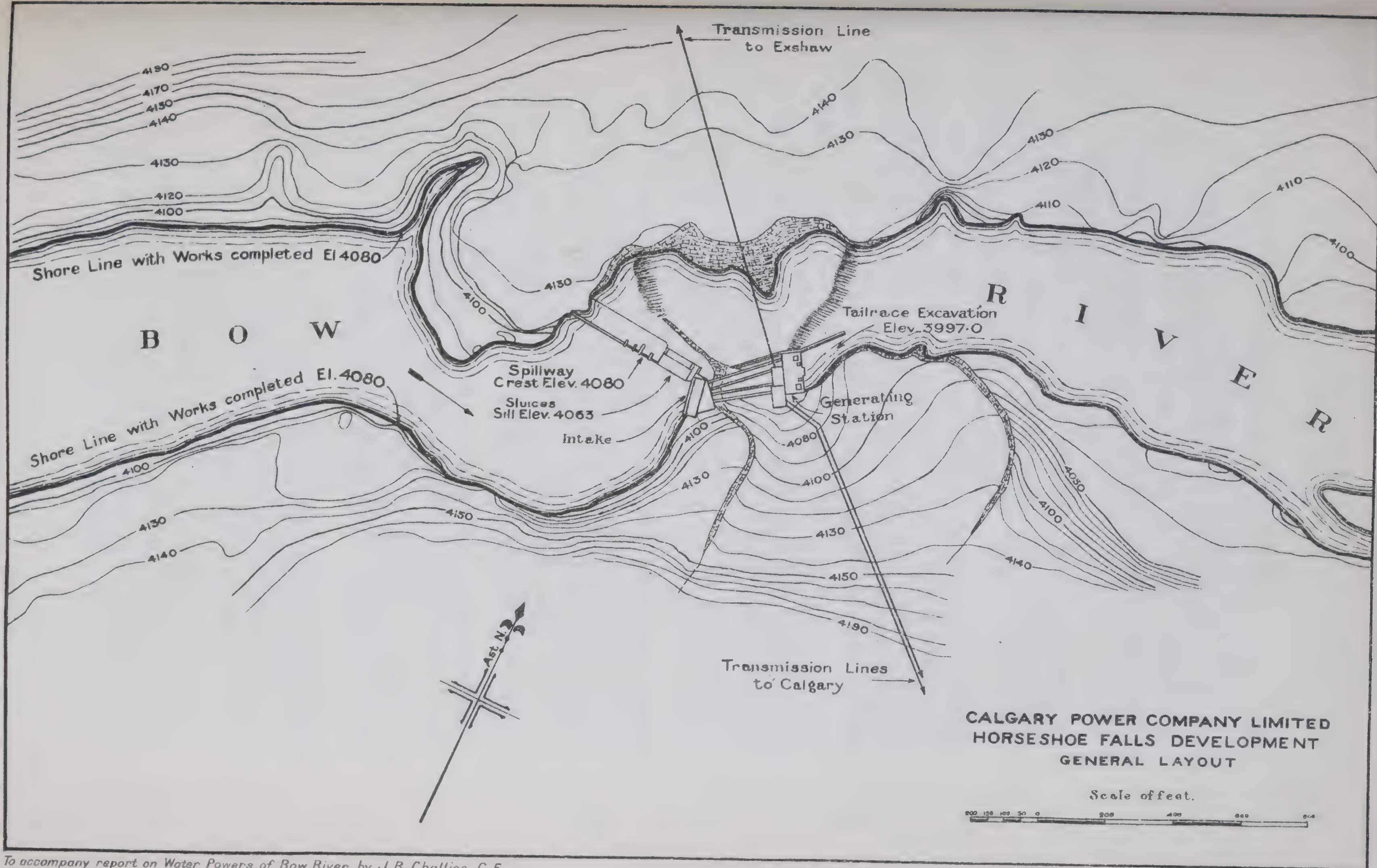
Conclusion.—Realizing the importance of the Bow river waters to every phase of the development of the district through which it flows, and recognizing the urgent necessity of having a practicable conservation scheme worked out and put into practice without delay, the investigations described herein were carried to completion with all reasonable thoroughness, and with every possible dispatch. They have been surprisingly gratifying, showing that it is economically feasible so to regulate the flow of the Bow river, by means of storage works in its upper waters, as to warrant the development at six power sites of over 45,000 continuous 24-hour wheel horse-power, all within 50 miles of the city of Calgary. At the same time, it has been shown that the using of these waters for power purposes above Calgary need not conflict with the consumption of the same water below Calgary for irrigation purposes; rather would the regulation proposed for power purposes be a distinct advantage to the extension of existing irrigation systems to their ultimate capacity, and also insure in the future the instigation of additional irrigation projects.

All of the present power and storage projects within the Bow River basin have been authorized under the Dominion water power regulations, which, in the way of limited grants, reasonable return to the Crown for the privileges, continuous control and periodic regulation of rates to consumers, the best possible physical use of the privilege, and continuous, beneficial operation provide for all that is essential in present day conservation principles regarding water power development. Care has also been taken to make all the present developments conform to any future comprehensive control scheme to be put into practice as soon as the necessities of the situation warrant.

Not only by the engineering investigations briefly described herein, but in the departmental administration of the resources referred to, the main purpose of the Dominion Water Power branch has been to realize, in the broadest sense of the term, "conservation."

Existing Developments on Bow River

Eau Claire Plant.—The first hydro-electric development on the Bow river, in the section from Calgary west, is that of the Eau Claire Lumber Company (Calgary Power Company), situated within the city limits of Calgary. The development makes use of the natural fall of the river by means of a diverting dam of pile and timber construction and a canal. The head developed is about 12 feet. The diverting dam is situated just above the bridge crossing the Bow river at Ninth street west, and the intake and canal are on the south side,



To accompany report on Water Powers of Bow River, by J.B. Challies C.E.

the canal following the south bank for about one-half mile. Advantage is taken of small islands or gravel bars, and these, together with timber pile structures, form the stream side of the canal. At the lower end an island forms the north side of the canal, or forebay, the original channel between it and the mainland forming the tail race. The present installation is for 600 horse-power.

The development is not on a permanent basis, and cannot be a very efficient one, though, with such a small head, and the restricted flow of the river that exists, no very large expenditure of money upon its development would be warranted.

This plant supplies current for lighting in the city of Calgary, having a franchise for the distribution of power. The water-power is supplemented by steam generated power, and in consequence the service is liable to very few interruptions, though, during the winter season, ice interrupts the operation of the water-power plant for considerable periods.

Lake Louise Power Plant.—An interesting power development in the Bow basin is that operated by the Canadian Pacific Railway Company in connection with the hotel at Lake Louise. This plant supplies light to the hotel at the lake, the station, and surrounding houses and buildings. During the summer of 1912, the plant was enlarged and changed, and the output increased.

The original plant was operated under a head of 45 feet, obtained by means of a concrete dam 75 feet long, built across the bed of Louise creek about a quarter of a mile below the outlet of the lake; from the intake, a 16-inch wood-stave, pressure pipe leads to the power house, the head being secured from the natural fall in the creek. A 35-k.w. machine, belted to the turbine, together with a switchboard, formed the station equipment.

The new installation, rendered necessary by the increased hotel accommodation, involves a concrete dam placed at the outlet of the lake, and forming part of the intake. The structure is in the nature of a bridge, having the spill sections situated between the piers, and is so built that the former high, low, and normal levels of the lake will still obtain.

Leading from the intake to the present power-house is a 20-inch wood-stave pipe line about 1,800 feet long, and giving a total head of 130 feet. The power-house has been enlarged, and a new unit connected to a generator of 75 k.w. installed, which, together with the other unit, can give an output of about 130 horse-power.

Horseshoe Fall Plant.—The largest completed power development on the Bow river (see plate facing page 208) is that of the Calgary Power Co. at Horseshoe fall, about 50 miles west of Calgary, where one of the very few concentrated falls on the Bow river is utilized.

At this point the river flows through a deep gorge, the walls and bed of which are formed of shale, banded with sandstone. At the point of development an anticline crosses the river. The rock has been considerably eroded, and there is a descent of approximately 25 feet. A concrete dam has been built across the gorge upon the lip of this outcrop, and this, with the natural fall, produces a head of 70 feet.

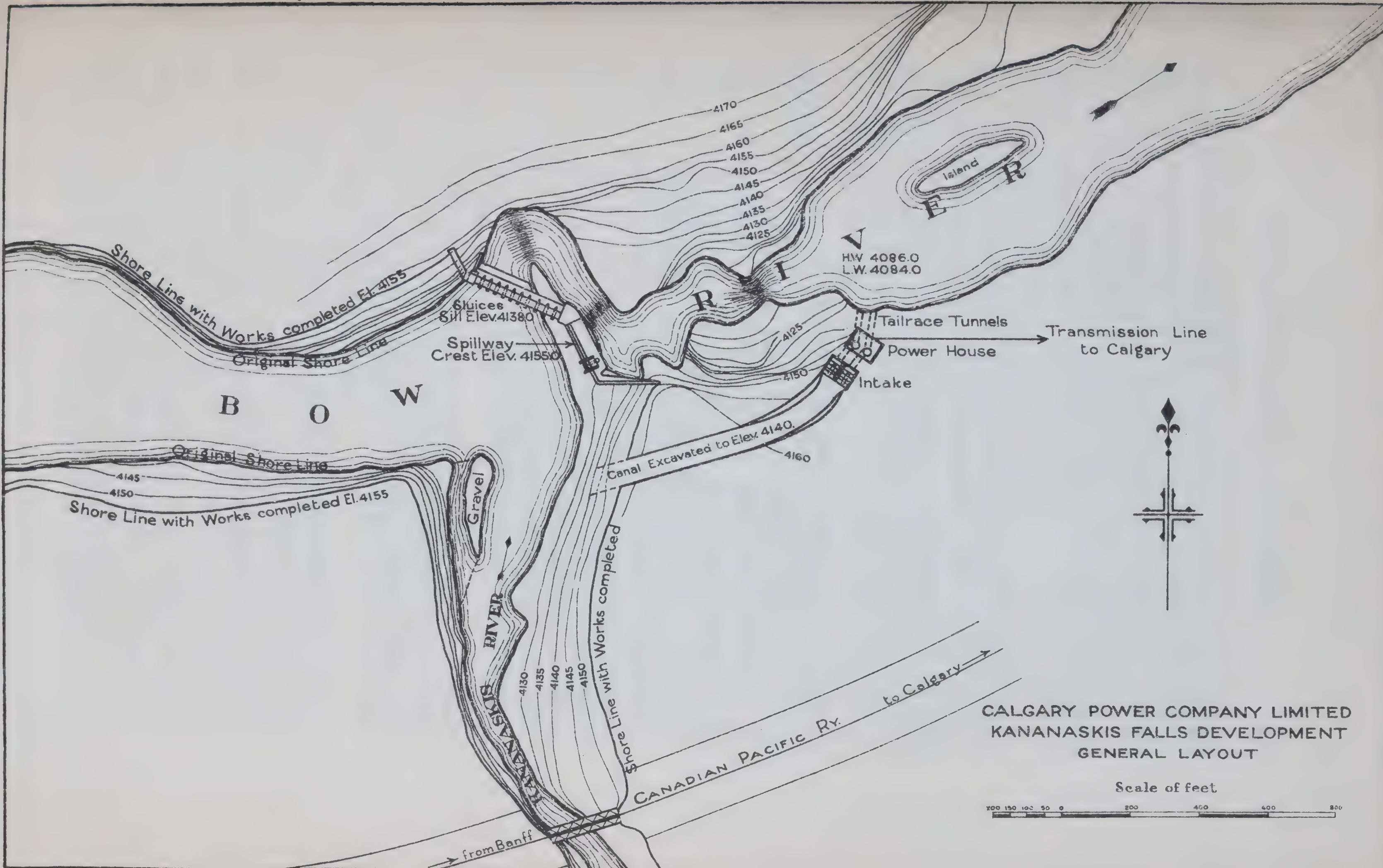
The dam is of solid spillway type, with an inspection and drainage tunnel. In addition to the spillway, there are eight sluiceways provided to take care of flood discharges. Four are simply stop-log openings, and four are supplied with sluicegates. The spillway section is 140 feet long, and, with the sluices, can discharge a flood of 40,000 c.f.s.

The intake structure is distinct from the dam, and occupies a position adjacent to it, approximately parallel to the stream flow. The water, which is admitted through racks and concrete chambers to the penstocks, is controlled by means of stop-logs and butterfly valves placed in the inlet chambers.

Provision has been made for four penstocks. The smaller ones are 9 feet 6 inches in diameter, and the larger, 12 feet, each delivering water to a single unit. They are approximately 250 feet in length, supported upon concrete piers, and protected from possible interference from the river at the lower end by a concrete wall. On account of the severity of the climate, it was considered necessary to house them, and a frame structure was built enclosing them for their full length.

The power-house, the main portion of which measures 118 feet by 56 feet, is situated in the gorge below the dam; it is of steel, concrete, and brick construction, and houses the turbines, generators, exciters, etc. At the rear of the power-house, and partly over the penstocks, the switch and transformer rooms are built. The tail race is protected from back water in time of flood by means of a wing wall, which separates the tail race from the river for some distance below the power-house.

The complete turbine installation consists of four turbines of the horizontal, double runner type, in steel wheel-cases, and two exciter turbines of the single runner type, the latter being of 330 horse-power capacity each. Two of the main units are of 3,750 horse-power capacity. The other two main units are of 6,000 horse-power each, and are controlled by Lombard governors. The smaller units are direct-connected to two generators of 2,500-k.v.a. capacity, being 3-phase, 60-cycles, 300-r.p.m. machines, and operating at 12,000 volts. The other two units are direct-connected to generators of 4,000-k.v.a. capacity, operated at 12,000 volts, 3-phase, and 60 cycles. The exciters are 175-k.w., 125-volt, and 700-r.p.m. machines.



To accompany report on Water Powers of Bow River, by J.B. Challies C.E.

The current is carried from the machines to two busses, one supplying the lines to Exshaw at 12,000 volts, the other supplying the step-up transformers, which raise the voltage to 55,000 for the Calgary lines. The transformer room contains four 3,000-k.v.a., 12,000 to 55,000-volt, oil-insulated, water-cooled, 3-phase transformers.

The company has three transmission lines in operation, one extending to Exshaw, a distance of eight miles, and the others forming a duplicate line to Calgary.

The Exshaw line supplies power to the cement plant at that place. It is a double-circuit, 3-phase, 12,000-volt line, strung on wooden poles; the six conductors are of No. 00 aluminum stranded cable. A telephone line is strung upon the same poles, and also a ground wire. The transformer station at Exshaw contains four 700-k.v.a. 12,000 to 600-volt, oil-insulated, water-cooled transformers, with lightning arresters and switching apparatus complete.

System of Transmission

The transmission line to Calgary is in duplicate; each is a single circuit, 3-phase, 55,000-volt line, the conductors being No. 0 aluminum, with telephone line and ground wire, carried on 40-ft. wooden poles. For the first ten and one-half miles from the power-house, the lines follow the line of the Canadian Pacific railway; they then separate. Line No. 1 turns south-east and joins the road outside the Indian reserve; thence it follows the Springbank road to within eight miles of Calgary. The total distance is nearly 51 miles from the power-house to the Calgary sub-station. The second line, from the point where line No. 1 turns south-east, runs about eight miles north of No. 1 to the south-east corner of township 24, range II, and thence to the sub-station parallels the other line. These lines transmit the power output of the plants at Horseshoe fall and at Kananaskis fall.

The Calgary sub-station, the capacity of which has recently been increased, provides for delivery of power to the city and the Canada Cement Company at three voltages, 12,000, 2,400, and 600 volts. This is accomplished by means of 3,000-k.v.a. and 1,250-k.v.a. transformers, with the necessary switch apparatus.

Kananaskis Fall Plant.—The site of the Kananaskis Fall plant (see plate facing page 208) is at the fall of that name on the Bow river. This fall is about two miles upstream from the Horseshoe Fall plant, and immediately below the junction of the Bow and Kananaskis rivers.

The total descent occurs in four sections, first, the rapids above the fall, and then a series of three falls, giving a total descent of, approximately, 55 feet. Above the rapids, the Bow is wide and fairly shallow; the banks are comparatively low, gradually increasing in height to the head of the falls. Below the falls the banks are perpendicular, the river flowing through a wide cañon. The banks of the Kananaskis are high,

and, on the west side, perpendicular, rising at least forty feet above the water. On the east side, the slope is more gradual for the first few hundred yards, but, beyond, they are high and abrupt.

The Canadian Pacific railway crosses the Kananaskis river about 250 yards above its mouth, and crosses the Bow river about one mile above the fall. The presence of these bridges affects developments at this point.

Plan of Development

The dam, at the head of the fall, diverts the water into a canal excavated on the south bank. The water is conveyed by the canal to an intake structure provided with racks and gates for controlling the flow. From the intake the water is conveyed in pressure tunnels to wheels placed in concrete scroll chambers situated below the power station, and thence, in draft tubes, to discharge tunnels leading to the river. The plant is designed for a working head of 70 feet.

The dam (see frontispiece) raises the water to an elevation of 4,198, which was determined by the elevation of the lower chord of the Canadian Pacific Railway bridge across the Kananaskis—4,204.75. The top elevation for flashboard and stoplogs, authorized by the Department, has been fixed at 4,198.75, or six feet below the bottom chord. The dam is built upon a ledge of rock extending practically across the river. The first section, approximately 200 feet long, is nearly parallel to the centre line of the canal; the shore end of this section is in the form of a retaining wall, while the outer 180 feet, or that portion nearest the angle, is of the spillway section, comprised of nine 17-foot openings, with 3-foot piers between.

The central section is 174 feet long, and is provided with eight 17-foot openings, with 3-foot piers between, and one 24-foot opening in the form of a spillway. The section is built partially upon, and partially below, the ridge rock mentioned, and is provided with two inspection tunnels, one above and one below the ridge; drains lead from the face of the rock to the inspection tunnel. In addition, a line of holes was drilled along the face of the dam down through the rock, and grouted, to close any seams that may underlie the dam.

The third section, forming the connecting link between the central section and the north bank of the river, runs upstream, making an angle of about 30 degrees with the centre portion. It is 268 feet in length between abutments, and is provided with sixteen 18-foot openings, with intermediate piers seven feet thick. It is proposed to control these 18-foot openings with stoplogs operated from a deck running the length of the dam, the bottom of the deck being at elevation 4,205. The elevation of sills of these openings has been finally determined as 4,181, working level being 4,198, which may be raised to 4,198.75 by

flashboards. This section is also provided with an inspection tunnel extending to the north bank, and having an extension in the form of a drift leading into the rock forming the north abutment; by means of this drift it is expected to cut off possible leakage around the end of the dam, and minimize danger to the structure in that respect. In addition, holes were drilled in front of this wall, and then grouted under pressure. Access to the inspection tunnels is gained by means of a shaft in the block, forming the junction between the second and third sections. This shaft leads to the tunnels, and also has an opening to the lower side of the dam; there is also a shaft in the north abutment of the dam, leading to the tunnels.

The discharging capacity of the structure is given below in tabular form. It should be noted that, with the exception of the rollway and log run, the discharge is dependent upon manual operation, and is not automatic except above elevation 4,198.

DISCHARGING CAPACITY OF KANANASKIS DAM

Elevation of headwater*	Discharge, in sec.-ft., through eleven 18-ft. sluices. Elevation of sill, 4,181	Discharge, in sec.-ft., through rollway and log run (automatic)	Discharge, in sec.-ft., through sluiceways and with stop-logs at elevation 4,198 (automatic)	Total discharge, sec.-ft.
4,195	34,600	0	0	34,600
4,196	38,400	0	0	38,400
4,197	42,400	0	0	42,400
4,198	46,100	0	0	46,100
4,199	50,300	940	660	51,240
4,200	54,400	2,820	1,750	57,220
4,201	58,800	5,450	3,425	64,250

The canal is excavated in rock, sand and clay. Owing to the high angle of dip, the rock surface appears as a series of saw teeth, the intervening spaces being filled with clay, sand, and gravel. Through the rock section, the canal is 72 feet wide, and, in the earth, 40 feet wide on the bottom, and 80 feet wide on top; the bottom elevation is 4,183. It is approximately 650 feet long.

The forebay to which the canal leads is divided into two bays, one for each pressure tube, and these again are divided into two openings by central piers. The openings are controlled by means of Tainter gates, though stop-logs, working in guides, may be placed in the entrance piers. Each bay is 34 feet wide, and each opening 14 feet, the dividing pier being six feet wide. The method of operating is mechanical.

*Elevations are above mean sea level, 43 feet having been added to original figures.

Wide passages from the forebay to the pressure tunnels, which are of reinforced concrete, afford easy access to the wheels situated in wheel-pits below the power-house.

Power Station and Equipment

The power station is built in excavation near the river bank. The necessity of placing the station in excavation was determined by the economical length of solid steel shafting connecting the generators and turbines. The sub-structure is of concrete, and the superstructure of steel and hollow tile construction.

In addition to the electrical and hydraulic equipment described below, the station is provided with a 50-ton crane, pumps, etc.

The electrical equipment consists of two vertical shaft type, direct-connected 3,750-k.v.a., 12,000-volts, 3-phase, 60-cycle generators, together with necessary exciters and motor generator set, switch apparatus, etc.; 12,000-volt busses are direct-connected to the Exshaw line, no step-up transformers being used. With this arrangement power may be delivered either to Exshaw or Calgary through the Horseshoe Fall plant, the two plants being connected.

The turbines are vertical shaft type, each of 5,800 horse-power capacity, with scroll cases formed in the concrete, giving easy entrance to the wheels. The method of installing these wheels is similar in many respects to that used at the large plant at Keokuk on the Mississippi.

Jumpingpound Creek

Jumpingpound creek is an important tributary of the Bow river, rising in numerous branches north of Fisher range and south of the Stoney Indian reserve. It follows a very irregular course in a general north-easterly direction, joining the Bow river from the south, 25 miles above Calgary.

The following is a summary of discharges at the gauging station established by the Irrigation branch of the Department of the Interior, near Jumpingpound:

MONTHLY DISCHARGE OF JUMPINGPOUND CREEK, NEAR JUMPINGPOUND P.O., ALTA.
(Drainage area, 187 square miles.)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1908				
June	829	236	414.8	2.21
July	186	57	101.9	.54
August	57	27	49.7	.27
September	57	20	28.7	.15
October (1-26)	40	27	39.5	.21

MONTHLY DISCHARGE OF JUMPINGPOUND CREEK, NEAR JUMPINGPOUND P.O., ALTA.—*Continued*

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1909				
May	491	76	222.8	1.19
June	311	96	188.6	1.01
July	236	57	121.3	.65
August	117	27	61.9	.33
September	27	20	24.7	.13
October	20	20	20.0	.11
1910				
April (9-30)	16	9	12.8	.063
May	27	16	22.4	.119
June	76	9	40.6	.216
July	16	3.5	6.56	.035
August	27	3.5	8.9	.042
September	117	9	64.0	.342
October	40	5	16.5	.088
1911				
May	392	30.8	127	0.679
June	548	52	216	1.155
July	548	73.4	205	1.096
August	1,200	106	357	1.909
September	366	109	184	0.984
October (1-19)	156	70.8	115	0.615
1912				
April	220	19	45.4	.24
May	308	89	175.9	.94
June	772	41	211.5	1.13
July	1,384	194	708.1	3.78
August	333	95	222.6	1.19
September	276	74	144.7	.77
October	131	78.2	104.6	.56
November (1-15)	950	95	95	.51
1913				
April (15-30)	196	22	88	0.486
May	441	20	144	0.796
June	778	70	221	1.22
July	240	53	119	0.657
August	374	42	134	0.740
September	137	20	52	0.287
October	32	24	26	0.144
1914				
April (4 to 30)	456	39	143.0	.761
May	78	39	57.3	.305
June	111	42	70.4	.374
July	111	14.4	40.3	.214
August	35	11.5	18.5	.098
September	19	8.6	11.6	.062
October	70	8.3	26.0	.138
1915				
March (15-31)	216	19	66	.357
April	48	18	28	.151
May	973	103	342	1.850
June	5,784	282	1,042	5.630
July	3,336	411	968	5.230
August	1,054	114	241	1.300
September	169	82	138	.746
October	155	109	129	.697

Ghost River

The Ghost river, which enters the Bow on the north side, about 35 miles west of Calgary, is 40 miles long, and has a drainage area of 367 square miles. Eight miles from the mouth, it divides into the Main branch and the North fork. Seven miles farther upstream, the main stream divides again, one branch retaining the name Ghost river, and the other being known as the South fork.

The sources of these three branches are at about the same altitude, 8,000 feet above sea-level. The South fork rises on the east slope of the Fairholme range, and issues, through the gap between End mountain and Saddle peak, into the foot-hill country; in a distance of eight miles, it descends 2,000 feet, or 250 feet per mile. The main branch of the Ghost river rises on the north side of the Palliser range; it flows south of Devils Head mountain and out into the foothills. The descent of this part of the Main branch is not as steep as that of the South fork, being approximately 133 feet per mile; the valley through which it flows is wide, and covered with gravel and debris carried down by the mountain tributaries. The North fork rises on the eastern slope of Castle Rock; its slope is more gradual than the others, and the major portion of its drainage area is in the foot-hills; it has numerous tributaries which rise in the swamps and sloughs.

Studies of this river have referred mainly to storage possibilities rather than to the development of power, but, even for storage purposes the Ghost is not well adapted. It might be considered advisable, at some future time, to create a storage of 4,000 acre-feet for the benefit of power plants on the Bow river, but any greater storage seems impracticable.

The following is a summary of discharges at the gauging station established by the Irrigation branch of the Department of the Interior at Gillies ranch:

MONTHLY DISCHARGE OF GHOST RIVER, AT GILLIES RANCH, ALTA.

(Drainage area, 360 square miles.)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1911				
August (17-31)	1,118	532	773	2.15
September	1,235	359	505	1.40
October	359	228	291	.81
November (1-11)	247	191	219	.61

Cascade River—Minnewanka Dam (Summer)

Cascade River—Minnewanka Dam (Winter)

MONTHLY DISCHARGE OF GHOST RIVER, AT GILLIES RANCH, ALTA.—*Continued*

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1912				
January	144	100	128	.35
February	112	96	99	.27
March	137	96	115	.32
April	342	76	134	.37
May	748	133	358	.99
June	1,371	96	300	.83
July	1,695	219	1,073	2.99
August	1,101	498	653	1.81
September	670	449	545	1.51
October	486	277	395	1.10
November	338	180	278	.77
December	294	176	196	.54
1913				
January	176	132	148	.411
February	143	112	132	.367
March	126	88	108	.300
April	572	88	212	.589
May	645	96	316	.879
June	1,225	143	371	1.03
July	777	400	553	1.54
August	600	344	428	1.19
September	488	311	353	.98
October	316	231	289	.803
November	287	192	230	.639
December	242	170	189	.525
1914				
January	174	94	150	.416
February	124	91	107	.297
March	128	95	113	.314
April	212	92	144	.400
May	215	113	168	.466
June	348	151	268	.745
July	348	250	276	.766
August	256	204	243	.675
September	261	191	206	.572
October	320	199	227	.630
November	230	172	187	.520
December	163	98	113	.309
1915				
January	118	92	107	.285
February	98	90	94	.251
March	98	91	95	.253
April	195	93	135	.360
May	550	145	334	.890
June	8,440	350	1,301	3.470
July	2,825	576	1,453	3.870
August	2,245	560	986	2.630
September	775	490	574	1.530
October	490	342	417	1.110
November	445	265	314	.837
December	475	167	244	.651

Kananaskis River

The Kananaskis river has a drainage area of 406 square miles between the lakes and the Bow river. It flows through a narrow valley confined by high mountains—the Kananaskis range forming the west boundary, and the Opal range the east. The tributaries are small mountain torrents; they are short and steep and carry down large quantities of gravel and detritus. The river valley is, on the whole, wide and flat. Where this is not the case, the stream flows between alternating high, rocky cliffs and gravel and clay banks, the latter being moraines. The valley floor is deeply covered with this deposit, through which the river has cut its way; where the valley is wide and flat, the stream is continually changing its course, especially during the high-water season. At one point, about four miles below Lower Kananaskis lake, a fall of approximately 25 feet occurs; for the rest of the course, no abrupt descents occur but the fall is considerable.

Investigations regarding possible storage on this river, in connection with the power-sites on the Bow, have revealed three favourable situations, at three-quarters, six and nine miles, respectively, above the mouth. The total storage capacity at the three sites would be more than 33,000 acre-feet and, in addition, it would be possible to produce 1,000 h.p. at the lowest site.

The following is a summary of discharges at the gauging station established by the Irrigation branch of the Department of the Interior near Kananaskis:

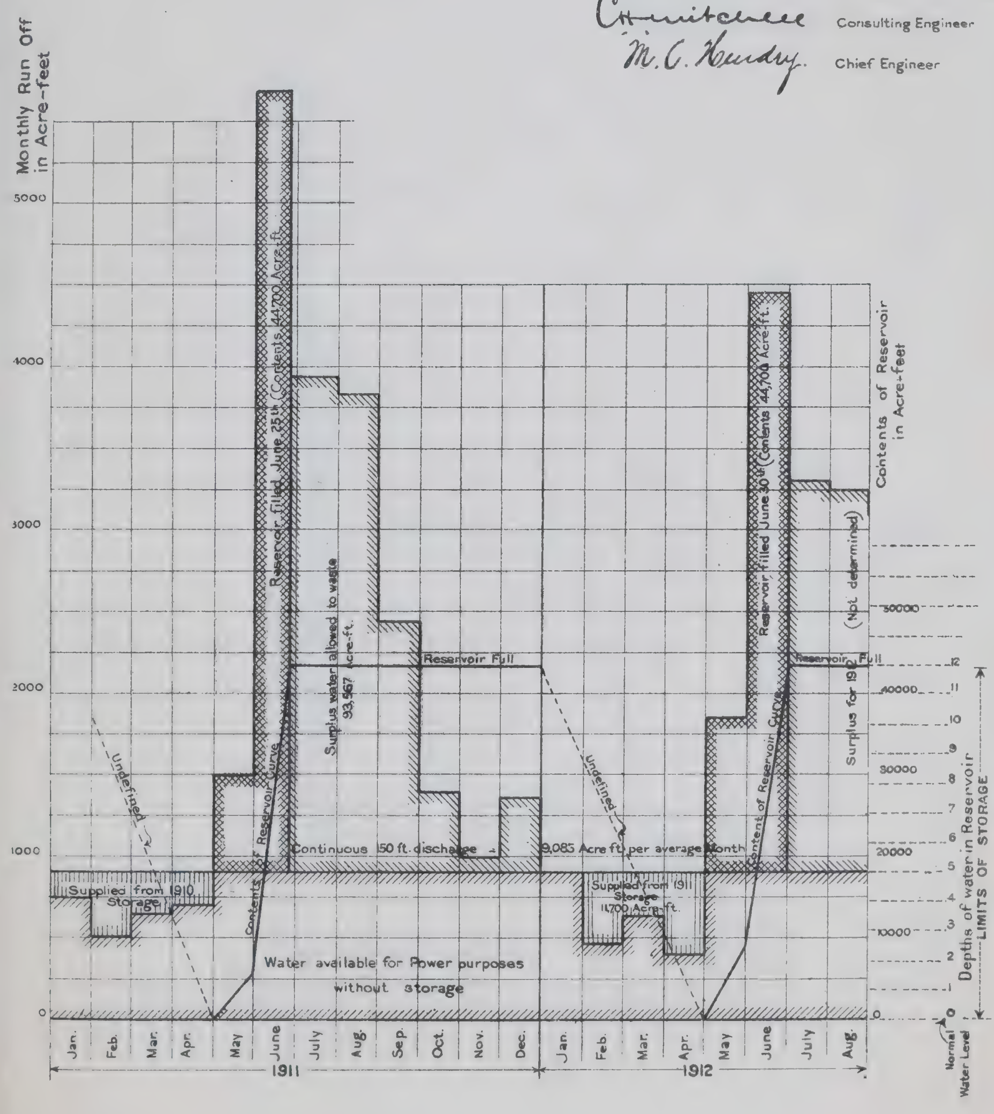
MONTHLY DISCHARGE OF KANANASKIS RIVER, NEAR KANANASKIS, ALTA.
(Drainage area, 395 square miles.)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1911				
September	1,168	430	715	1.81
October	415	187	300	.76
November (1-11)	187	111	152	.38
1912				
January	160	123	136	.34
February	132	118	129	.33
March	132	113	129	.33
April	149	108	128	.32
May	866	120	477	1.21
June	3,006	478	1,582	4.00
July	3,258	1,262	1,996	5.04
August	3,222	1,014	1,424	3.60
September	898	424	653	1.65
October	414	314	376	.95
November	314	120	252	.64
December	440	72	204	.52

LAKE MINNEWANKA STORAGE

Diagram shewing Discharge in Acre-Feet, from Jan. 1911 to Aug. 1912
also
Process of Filling Basin, and providing for a constant Discharge of 150 Sec-Ft. with 12 ft. of Storage

C. H. Mitchell Consulting Engineer
M. C. Hendry Chief Engineer



To accompany report on Water Powers of Bow River, by J.B. Challies. C.E.

LAKE MINNEWANKA STORAGE

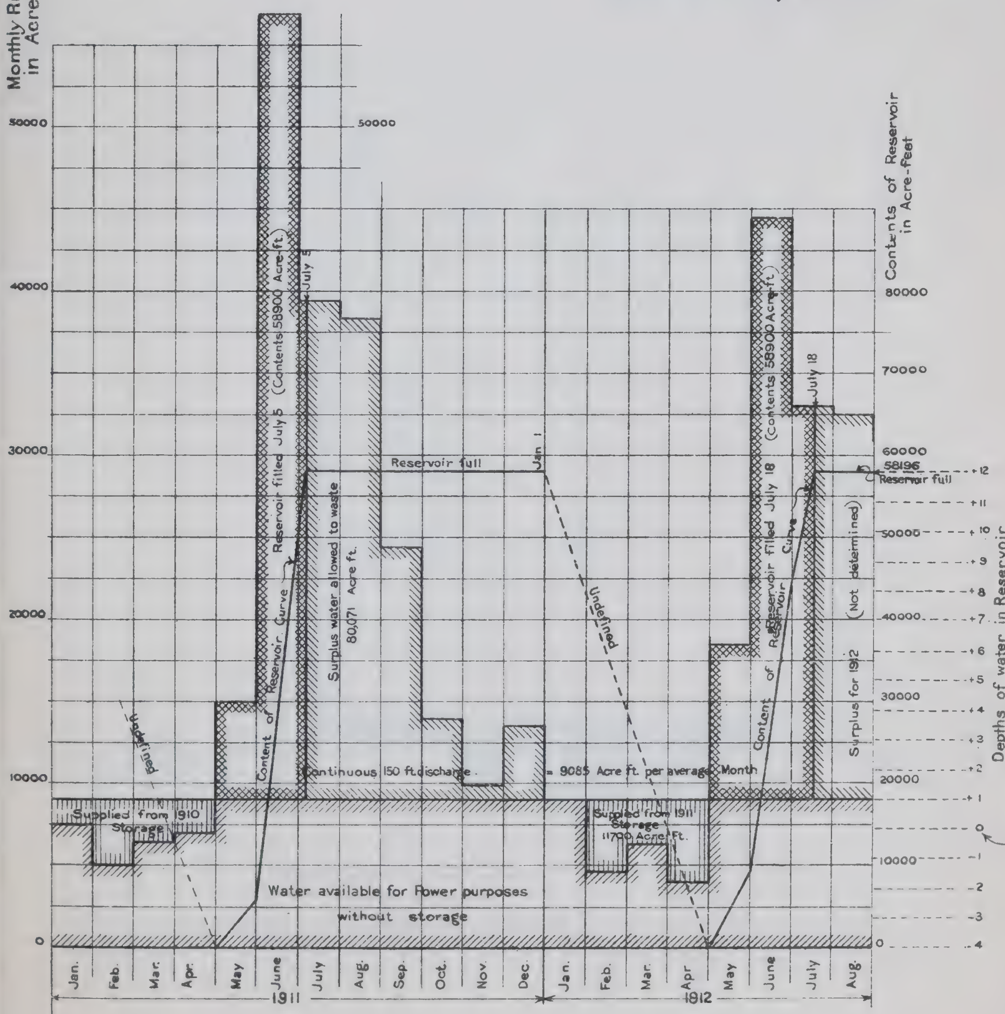
Diagram shewing Discharge in Acre-Feet, from Jan. 1911 to Aug. 1912

— also —

Process of Filling Basin, and providing for a constant Discharge of 150 Sec-Ft. with 16 ft. of Storage

C. H. Mitchell — Consulting Engineer

M. C. Hendry. — Chief Engineer.



To accompany report on Water Powers of Bow River, by J. B. Challies C. E.

LAKE MINNEWANKA STORAGE

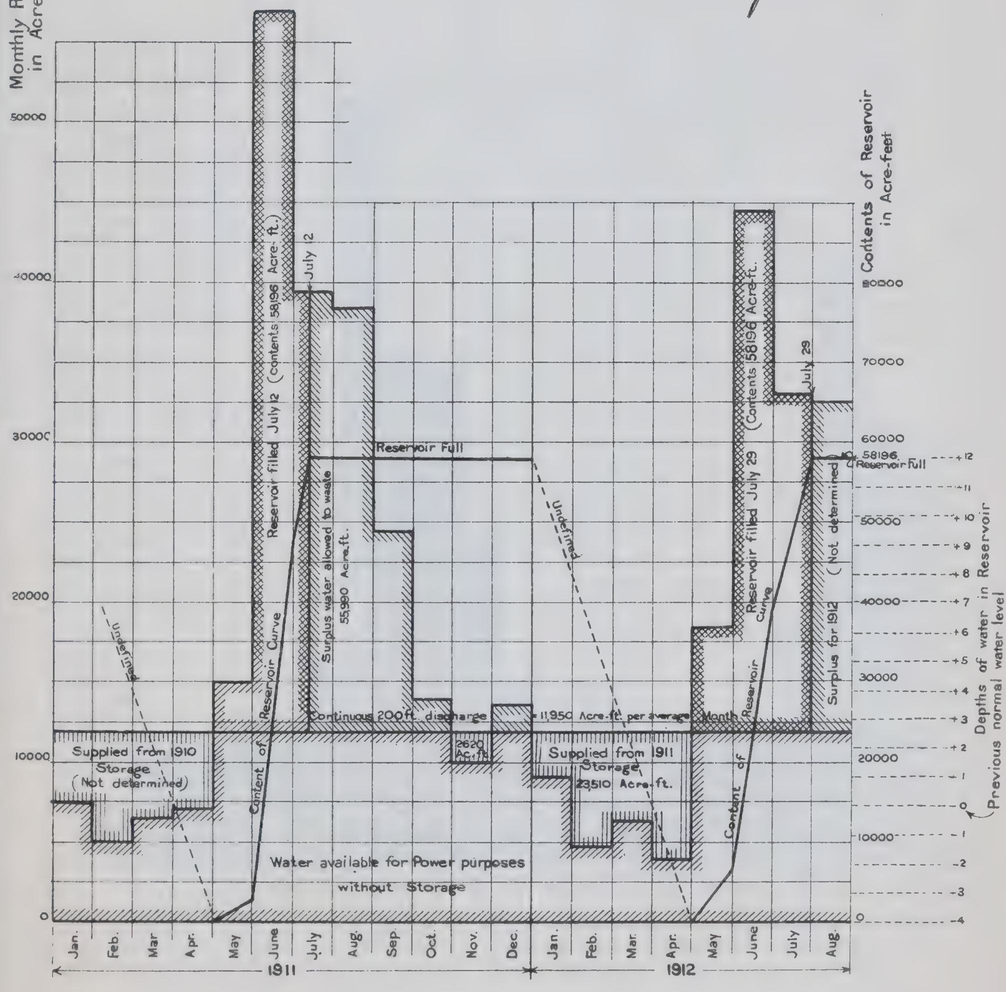
Diagram shewing Discharge in Acre-Feet, from Jan. 1911 to Aug. 1912

also

Process of Filling Basin, and providing for a constant Discharge of 200 Sec.-Ft. with 16 ft. of Storage

C.H. Mitchell Consulting Engineer

M. C. Hendry Chief Engineer

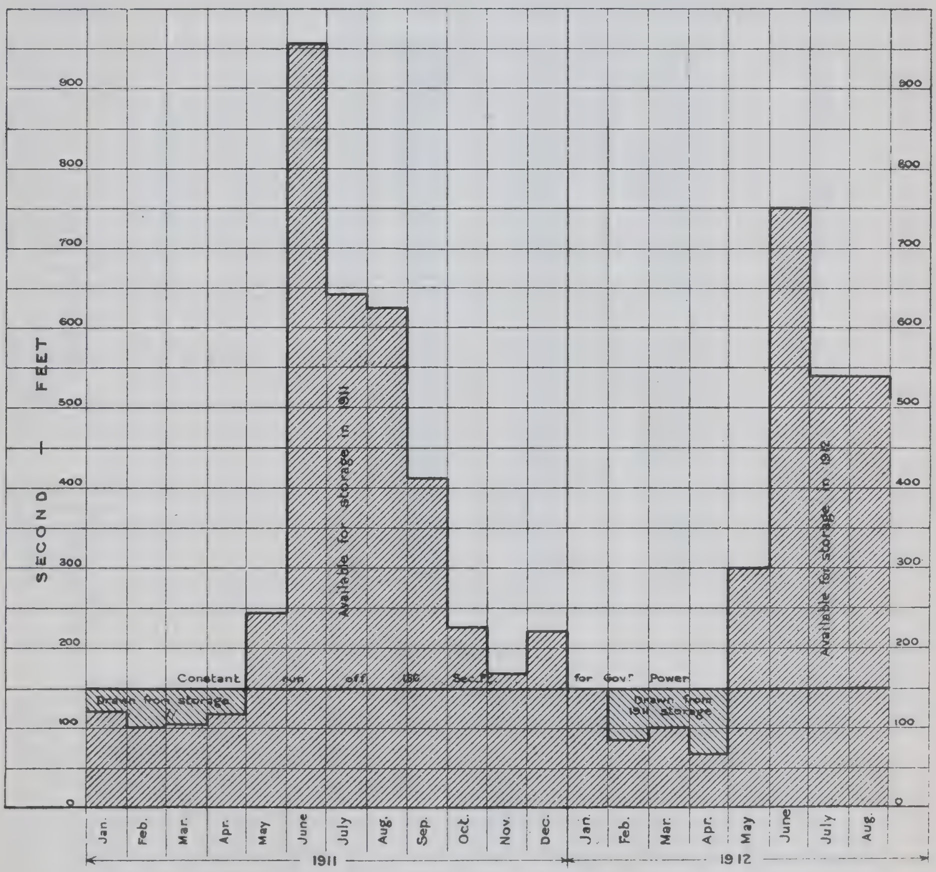


To accompany report on Water Powers of Bow River, by J.B. Challies C.E.

LAKE MINNEWANKA STORAGE

Hydrograph of Mean Monthly Flow, from January 1911 to August 1912
— showing —
Conditions imposed by a constant Run Off of 150 Sec.Ft.

C. H. Mitchell Consulting Engineer
M. C. Hendry Chief Engineer



To accompany report on Water Powers of Bow River, by J.B. Challies C.E.

MONTHLY DISCHARGE OF KANANASKIS RIVER, NEAR KANANASKIS, ALTA.—*Continued*

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1913				
January	195	134	168	.426
February	190	140	169	.428
March	170	112	136	.345
April	258	112	178	.451
May	1,648	173	492	1.25
June	2,150	1,406	1,712	4.34
July	1,545	913	1,245	3.15
August	1,685	1,015	1,277	3.23
September	1,731	700	989	2.50
October	764	286	507	1.28
November	340	258	306	.775
December	277	200	226	.572
1914				
January	206	81	142	.360
February	180	75	133	.337
March	180	127	153	.388
April	224	139	169	.428
May	1,162	249	722	1.830
June	2,370	1,090	1,653	4.180
July	2,168	1,096	1,702	4.300
August	1,198	700	961	2.440
September	720	489	599	1.520
October	700	426	542	1.370
November	412	252	311	.787
December	275	110	197	.500
1915				
January	123	75	97	.249
February	163	97	145	.372
March	163	107	133	.341
April	383	128	200	.513
May	1,296	461	921	2.360
June	5,380	1,109	1,893	4.850
July	3,217	1,589	2,010	5.150
August	1,645	1,119	1,363	3.490
September	1,119	646	811	2.080
October	630	383	480	1.230
November	400	296	328	.841
December	298	204	266	.682

Cascade River

Cascade river, one of the most important tributaries of the upper Bow river, is of particular interest in connection with the Minnewanka Lake storage and power project.

Minnewanka Storage and Power Dam.—This concrete structure, 100 feet long and 55 feet in upstream height, was built by the Calgary Power Company primarily to furnish storage in connection with that company's power plants at Horseshoe fall and at Kananaskis fall. As the dam was constructed in a cañon at the junction of Cascade river

and Devil creek, and immediately above a power site on the Cascade, the Dept. of the Interior took advantage of the situation. The company's original plans had provided a simple concrete structure with four spillway sections, but, upon demonstration by the Water Power branch of the possibilities of a future power project, to be constructed and operated in the interest of the Rocky Mountains National Park, the company readily agreed to alter its original designs, and have one of the spillway openings used for an intake for the project. Accordingly, in place of the fourth sluiceway to the left of the dam, a penstock opening has been provided, with all permanent works necessary for racks, intake piers, stop-log openings, etc. A steel thimble, to form the intake end of a penstock five feet in diameter, was placed.

This dam was commenced early in March, 1912, and hurriedly completed in time to store the summer's flood of 1912 for use during the following winter.

Cascade Power Project.—The cañon of the Cascade river, in which it is proposed to develop power, is about seven miles from Banff and lies directly below the junction of Cascade river and Devil creek, the latter carrying the discharge of lake Minnewanka. The area tributary to the river at this point is approximately 220 square miles, of which lake Minnewanka forms about 6 square miles. The greater portion of this basin lies at considerable altitudes, the entire water supply coming from mountain streams, springs, and glaciers.

Jurisdiction of Parks Branch

As the project lies wholly within the Rocky Mountains Park, any development at this point will be under the jurisdiction of the Parks branch of the Department of the Interior. All privileges, such as land, water, and rights-of-way, are vested in the Crown. The natural conditions on the river no longer obtain, since the storage and regulation works are complete and in operation; but the influence of these works upon the operation of a power plant at the point contemplated will be entirely beneficial.

Joint Benefit of Storage

In authorizing the construction of the Minnewanka dam by the Calgary Power Company, it was realized that this company would not be the only beneficiary from the storage created; that it was very probable that other plants on the Bow river would be built, which would receive direct benefit from this storage. Provision was made, therefore, for the absolute control by the Dept. of the Interior of the operation of the dam. Provision was also made for reconsideration and reapportionment of the rental payable to the Department by the Calgary Power Company or any other company deriving benefit from the storage thereby created.

With respect to the proposed power project on the Cascade river immediately below the dam, provision was made for discharge or re-

lease through the dam of a continuous minimum volume of water of 150 cubic feet per second, which may be used for power purposes within the Rocky Mountains National Park. The release of such water through the dam shall at all times be under the full control of the Department.

During the early part of the flood season, water will be stored in Minnewanka lake. This storage should be completed not later than July 15, in any season, after which date water will probably be wasted over the dam. A flow over the dam, greater than 150 second-feet, is practically assured during part of July, August and September, so that the greatest power will be available during the summer months. This period synchronizes with the time of heaviest tourist traffic and of consequent heaviest power load, a very fortunate combination of circumstances.

Tourist Traffic

It is to be noted, however, that the tourist traffic in Rocky Mountains Park during the winter months is steadily increasing. With vigorous encouragement of the use of this park, it is probable that, in the not distant future, the power load during the winter months for park purposes will be equal to, if not greater than, that for the summer months. The Minnewanka dam produces at least half the available head to be developed for the Cascade power project, the other half being due to the natural fall of the river between the dam and the proposed power site. As the pond above the dam is primarily for storage purposes, there will necessarily be a fluctuation in level. This will not, however, affect the head unfavourably, for the low-working head will occur during the winter months, when the load will be small, at least for the early stage of the development.

As the Minnewanka dam provides a total storage possibility of 58,080 acre-feet, of which 44,080 acre-feet only is guaranteed to the power company, 14,080 acre-feet of surplus storage can be made available for the Cascade project.. This surplus storage will allow of a continuous flow of 200 feet per second. The available head, when the storage basin is full, will be 64 feet, of which 60 feet may be assumed to be effective head. With this head, and a flow of 200 second-feet, an electrical output at the power station may be secured of at least 900 horse-power, of which 825 horse-power could be delivered in Banff ready for delivery to the consumers. Owing to the loading conditions imposed, this flow of 200 c.f.s. could not be utilized continuously, and hence an overdraft for peak loads would be available of probably 330 c.f.s. It is on this basis of flow, *i.e.,* 330 c.f.s., that the proposed development has been worked out.

Under the method of development contemplated, it is proposed to construct all the general works, such as power station, tail race, etc.,

for the full capacity of the plant, but only sufficient equipment will be placed in the station at first to develop two-thirds of the proposed station capacity, the remainder to be added as the demand warrants.

Method of Development

The scheme of development has been worked out by the engineers of the Dominion Water Power branch, in collaboration with, and under the direction of, Mr. C. H. Mitchell, whose full report has been published in the annual report of the Dept. of the Interior for 1913-1914.

Dam.—The Minnewanka storage dam at the upper end of the cañon, to be used as an intake for the power project, is of concrete masonry construction, and is provided with means for discharging water either through stop-log spillways, or through a low level sluiceway controlled by a gate valve.

At one side of the cañon one of the stop-log openings was modified to be used as an intake to the penstock, provision being made for screens, and a steel thimble five feet in diameter inserted in the opening to provide a connection to the penstock. This thimble is set at such an elevation that the water may be drawn down in the basin without breaking the water seal on the entrance to the penstocks. It should be pointed out that the power project begins at the outside end of the thimble; the cost of the dam, thimble, etc., is charged against the cost of creating storage.

Penstock or Flume.—The penstock connection to the thimble will lead along the cliff for a short distance, and then enter a tunnel driven in the rock along the south side of the cañon; the tunnel will connect with a steel penstock so designed and placed as to provide an unsupported crossing of the river at this point. After crossing the river, the steel penstock will join one of wood, seven feet in diameter, which will convey the water to a point just outside the power house; it will be under pressure, and generally in cut, though, for a length of approximately 150 feet, it will be carried above the ground on concrete piers.

The lower end of the penstock at the power-house will be steel pipe, eight feet in diameter, from which the necessary connections to the turbines will branch. These branches will be fitted with valves to control the flow, and the penstock itself connects directly with a steel surge tank built upon the side of the hill. The tank will be approximately 12 feet in diameter, and of such height as to be above the highest level of lake Minnewanka, and thus prevent spilling. It will provide sufficient hydraulic regulation in the operation of the long pipe line.

Power Station.—The power-house, which will be placed in part of the present river bed, will be of concrete construction, protected on the

river side by a wall, both upstream and downstream, from the power-house. The equipment will consist of three units; each turbine will be of 600 horse-power capacity, direct connected to 350-k.w. generators, the latter having exciters mounted on the outer end of the shaft. The generators will be connected through the necessary switch and protecting apparatus to the transmission line, no step-up transformers being necessary.

It is proposed to install two units at first, one of which will act as an auxiliary; the third will be added when the power load demands it.

The following is a summary of discharges at the gauging station established by the Irrigation branch of the Department of the Interior at Bankhead:

MONTHLY DISCHARGE OF CASCADE RIVER, AT BANKHEAD, ALTA.
(Drainage area, 246 square miles)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1911				
August (16-31)	714	499	624	2.54
September	501	298	411	1.67
October	296	156	226	.92
November (1-6)	175	160	166	.67
1912				
January (1-4, 8-31)	206	70.8	148.7	.61
February	119	60.8	85.2	.34
March (1-21, 27-31)	303	58	101.6	.41
April	261	42.6	66.6	.27
May	532	62.1	301.4	1.22
June	1,500	Nil	648.4	2.63
July	1,500	8.5	337.8	1.37
August	1,695	10	788	3.20
September	437	Nil	289.2	1.18
October	1,362	232	278	1.13
November	724	107	290.4	1.18
December	522	74	313.8	1.28
1913				
January	225	128	166	.67
February	169	106	140	.57
March	225	150	184	.75
April	513	283	342	1.39
May	551	3	259	1.05
June	1,240	3	878	3.57
July	945	101	417	1.70
August	905	266	583	2.37
September	507	86	350	1.42
October	252	101	200	.81
November	805	194	377	1.53
December	975	374	637	2.59
1914				
January	372	155	217	.88
February	180	70	91.7	.37
March	164	77	98.4	.40
April	133	9.2	90.4	.37
May	414	2.6	126	.51

MONTHLY DISCHARGE OF CASCADE RIVER, AT BANKHEAD, ALTA.
Continued

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1914—(*Cont.*)				
June	1,400	5.1	890	3.62
July	1,014	214	625	2.54
August	322	36	172	.70
September	248	36	74.2	.30
October	259	82	206	.84
November	313	163	224	.91
December	422	124	158	.64
1915				
January	399	119	159	.652
February	503	146	266	1.090
March	476	285	379	1.550
April	356	161	216	.885
May	166	5.5	57	.234
June	2,607	51	843	3.460
July	2,270	1,149	1,444	5.920
August	1,178	286	764	3.130
September	472	132	235	.963
October	246	157	202	.828
November	286	205	238	.976
December	180	143	166	.680

Spray River

Spray river, one of the largest tributaries of the Bow west of Calgary, joins that stream in the Rocky Mountains park, at Banff, directly below Spray fall. It is between 40 and 50 miles long from source to mouth, and has a drainage area of 310 square miles. About eight miles above the mouth, the river divides; the eastern branch, the smaller, flows from the valley between mount Rundle and Goat mountain. From the junction upstream, for about 17 miles, the west branch flows through a narrow valley, with a total descent in this distance of 750 feet. In this stretch there are very few important tributaries. It is quite possible that a limited amount of power, such as that to be developed on the Cascade in connection with the storage at lake Minnewanka, might be developed on this river.

The Spray lakes, three in number, lie to the north of the river. They are connected with it by a stream about one-half mile in length, which enters just below the mouth of Hogarth creek. As a capacity of 171,000 acre-feet is available, the possibilities of storage on these lakes are encouraging.

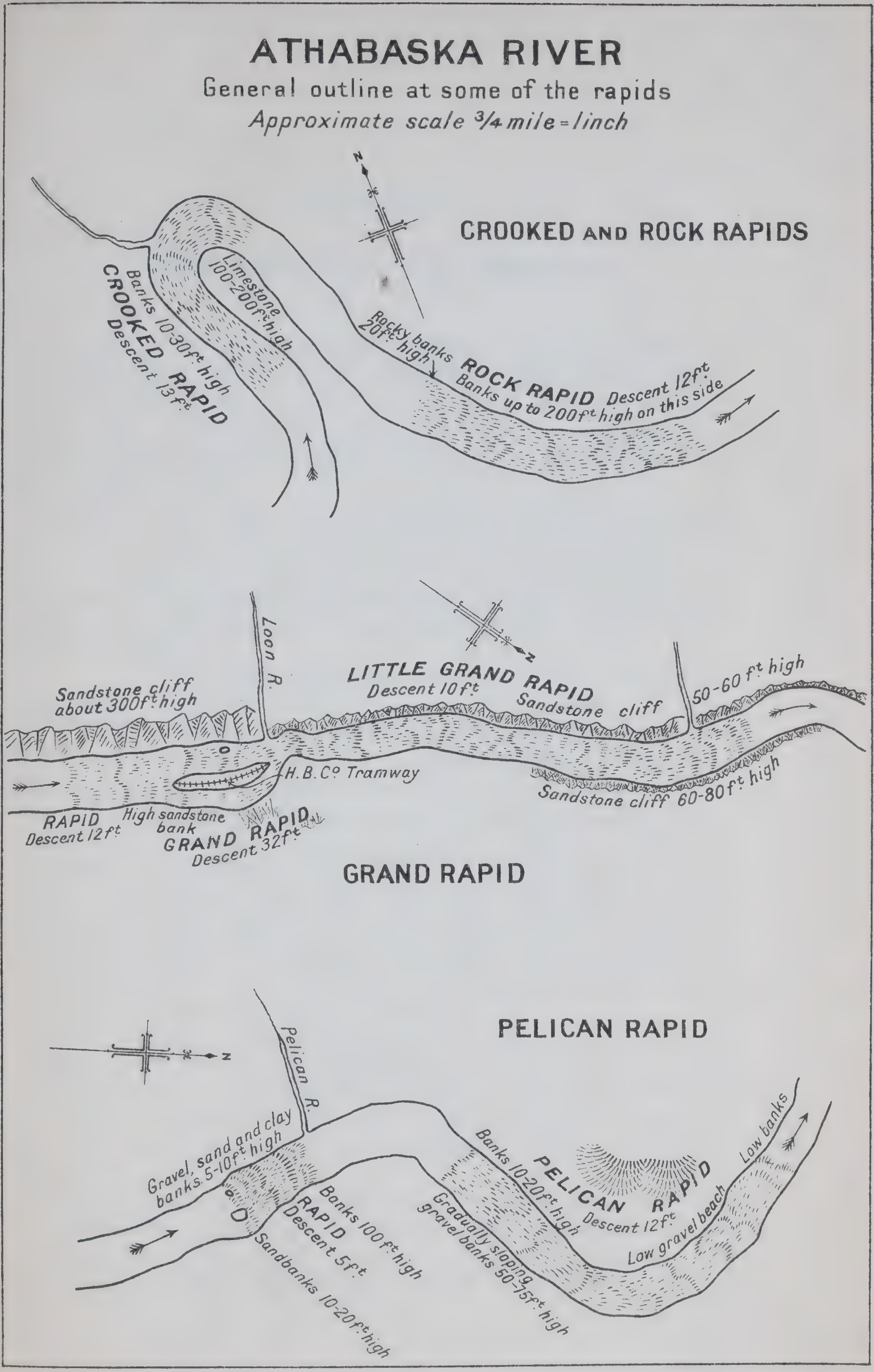
The following is a summary of discharges at the gauging station established by the Irrigation branch of the Department of the Interior near Banff:

MONTHLY DISCHARGE OF SPRAY RIVER, NEAR BANFF, ALTA.
(Drainage area, 305 square miles)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1910				
July (15-31)	1,510	862	1,153	3.78
August	1,042	450	784	2.56
September	545	450	490	1.60
October	545	345	443	1.45
December (4-31)	390	150	237	.77
1911				
January	255	156	199	.65
February	153	138	146	.48
March	157	135	143	.47
April	233	116	156	.51
May	512	246	389	1.27
June	2,640	815	2,011	6.58
July	2,332	990	1,523	5.00
August	1,020	635	829	2.72
September	752	400	544	1.77
October	395	232	315	1.03
November	300	180	226	.74
December	260	188	209	.69
1912				
January	155	146	150	.49
February	150	132	141	.46
March	141	75	108	.35
April	158	108	134	.44
May	912	152	517	1.69
June	2,530	469	1,405	4.60
July	1,830	1,065	1,398	4.58
August	1,056	778	907	2.98
September	826	499	664	2.17
October	524	318	428	1.40
November	330	144	272	.89
December	395	144	237	.78
1913				
January	222	180	202	.663
February	180	140	151	.496
March	158	136	146	.480
April	260	143	191	.627
May	1,985	221	535	1.75
June	2,960	1,432	2,144	7.03
July	1,596	741	1,041	3.42
August	1,078	668	908	2.98
September	1,096	562	703	2.30
October	556	275	447	1.47
November	352	231	298	.978
December	278	184	225	.738

MONTHLY DISCHARGE OF SPRAY RIVER, NEAR BANFF, ALTA.—*Continued*

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1914				
January	227	150	196	.642
February	184	160	170	.557.
March	180	126	167	.548
April	238	152	180	.590
May	1,196	290	731	2.400
June	3,041	1,039	1,942	6.360
July	2,565	1,028	1,736	5.690
August	1,028	562	772	2.530
September	575	409	491	1.610
October	625	430	533	1.750
November	446	227	333	1.100
December	240	150	183	.600
1915				
January	198	162	182	.617
February	189	167	179	.607
March	187	148	172	.583
April	519	163	276	.936
May	909	486	675	2.290
June	2,300	760	1,196	4.050
July	2,085	1,188	1,477	5.010
August	1,259	691	929	3.150
September	712	405	507	1.720
October	426	329	364	1.230
November	329	210	257	.871
December	209	173	193	.654


ATHABASKA RIVER
General outline at some of the rapids
Approximate scale 3/4 mile = 1 inch
CROOKED AND ROCK RAPIDS
N
Banks 10-30 ft. high
CROOKED RAPID
Descent 13 ft.
Limestone 100-200 ft. high
Rocky banks 20 ft. high
ROCK RAPID Descent 12 ft.
Banks up to 200 ft. high on this side
GRAND RAPID
Loon R.
LITTLE GRAND RAPID
Descent 10 ft.
Sandstone cliff
Sandstone cliff about 300 ft. high
50-60 ft. high
H.B.Co Tramway
Sandstone cliff 60-80 ft. high
RAPID
Descent 12 ft.
High sandstone bank
GRAND RAPID
Descent 32 ft.
N
PELICAN RAPID
Pelican R.
Gravel, sand and clay banks 5-10 ft. high
RAPID
Descent 5 ft.
Banks 100 ft. high
Sandbanks 10-20 ft. high
Gradually sloping gravel banks 50-75 ft. high
Banks 10-20 ft. high
PELICAN RAPID
Descent 12 ft.
Low gravel beach
Low banks

CHAPTER XII

Athabaska River and Tributaries

The Athabaska is the most southerly of the three great tributaries of the Mackenzie. It rises in the watershed range of the Rocky mountains in lat. 52° 15′ N., and, after a north-easterly and northerly course of 780 miles, empties into lake Athabaska. Thence, its waters are conveyed by Slave river to Great Slave lake and from there to the sea by the Mackenzie river.

Between Lesser Slave river and Athabaska, a distance of 66 miles, the course of the Athabaska river is first easterly and then southerly. In width it averages about 250 yards, occupying a valley 350 feet deep and approximately two miles wide. The current has a fairly uniform rate of from three to four miles per hour and the river is easily navigable.

Obstructions to Navigation

From Athabaska to the Grand rapid, a distance of 153 miles, the general course is northerly; its width varies from 250 yards to 400 yards, and the current, except for occasional accelerations, averages from three to four miles per hour as far as the mouth of the Pelican river. Between Pelican river and the Grand rapid, several rapids obstruct navigation in low water, but, at medium or high water, they are easily ascended and descended by the steamer plying between Athabaska and the Grand rapid. This portion of the valley is from 300 to 400 feet deep, while, owing to the plastic character of the clay shales, the banks consist of a succession of slides. The grade of the river, between the mouth of Lesser Slave river and the head of the Grand rapid, averages 2·6 feet per mile, or a total descent of 575 feet.

At the Grand rapid, the character of the Athabaska changes entirely. Its grade increases greatly and, in the next 76 miles, or as far as its junction with Clearwater river, there are swift and dangerous rapids at intervals of a few miles. The Grand rapid is caused by the river cutting through a soft, sandstone terrace of Cretaceous formation.

After passing the Grand rapid and the succeeding rough water, the Athabaska flows quietly for over 20 miles before rushing down the Brûlé rapid. In this stretch the valley is deep and gorge-like. The banks are from 500 to 600 feet high, and are often terraced by differ-

ential denudation. At the Brûlé rapid the stream is shallow and contains many boulders.

The Brûlé rapid is succeeded by 16 miles of smooth water, below which the river falls in quick succession over the Boiler, Middle and Long rapids; all of these occur within a stretch of seven miles. The three rapids, which are similar in character to the Brûlé, owe their existence to a steeper descent than usual, combined with an accumulation of boulders in the channel of the river.

Five miles below Long rapid, the river makes a sharp bend at Crooked rapid, where two ledges of limestone project into the stream from the right side.

Below Crooked rapid the stream falls over several limestone ledges, forming Rock rapid and the Little Cascade and Big Cascade. Thence, it descends unobstructed for eight or nine miles, to Mountain rapid which, like the Cascades, is formed by a low limestone ledge.

The descent of the Athabaska, between the head of the Grand rapid and the Clearwater confluence, a distance of 76 miles, totals 410 feet, an average of 5·4 feet per mile.

River Changes Character

Below the confluence with the Clearwater river the character of the Athabaska again changes greatly. The rapids disappear and the river, enlarged to a third of a mile in width, flows smoothly at an average rate of three miles per hour. The valley increases in width, while the banks gradually decrease from an elevation of about 400 feet at the forks to the level of the delta at the entrance to lake Athabaska. In passing through the delta the channel divides into several branches; new channels are constantly being opened and old ones closed by the spring floods. From the forks to the head of the delta, a distance of 130 miles, and thence to lake Athabaska, an additional 31 miles, the Athabaska contains no obstruction to navigation. The steamer "Grahame," owned by the Hudson's Bay Company, has been plying on this portion of the river for several years.

The foregoing general description of the river may be supplemented by a more detailed description of its rapids and flow. During the summer of 1911 the hydro-electric engineer of the Commission of Conservation examined these rapids, and the following extract is quoted from his report:

> The difference of levels in the various rapids was obtained by means of aneroid readings; in most cases readings were taken when descending and checked when ascending the river. At the time of observation (Aug. 11 to 21) the river was unusually high for the season of the year; the highest water, usually occurring in June or July, is about six feet higher and the lowest stage, at the end of April or beginning of May, about four feet lower

than that at which the observations were taken. Illustrating the sudden fluctuations to which this river is subject, during one night, Aug. 23-24, its level rose some six feet, almost reaching the high water mark. This, of course, is unusual, and must have been caused either by excessive rain near the head-waters or by melting snow in the mountains, as it was afterwards ascertained that a rise had also been observed in the Smoky river on or about the same date, and on the North Saskatchewan river at Prince Albert on Aug. 28.

The rapids of the Athabaska river are long and have relatively low heads; these conditions naturally imply that the wide fluctuation in the flow of the river will materially affect the working heads when developed. Similar conditions occur in some of the rapids of the Saskatchewan river, where, to overcome the difficulty, it has been suggested that each turbine unit be provided with an auxiliary turbine which can be coupled to the shaft when the head is low and there is an abundance of water, or thrown out of use when the flow lowers and the head becomes normal. The problem may be solved in a similar manner when the rapids of the Athabaska are being developed.

Between Athabaska and the mouth of Lesser Slave river, there is only one important rapid. It is simply a swifter part of the river occurring at a point seven miles below the mouth of the Lesser Slave river, where the Athabaska is divided into two channels by an island; the descent in this rapid is ten feet in three-eighths of a mile.

Pelican Rapid, commencing three-quarters of a mile below the Pelican river, or 41 miles above the Grand rapid, has a descent of twelve feet in two miles. Just above this another small rapid, ending at the mouth of the Pelican river, descends five feet in one-half mile.

Stony Rapid, 37 miles above Grand rapid, has a descent of five feet in one-third of a mile.

Rapid, seven miles below Stony rapid, has a descent of eight feet in one mile.

Joli Fou Rapid, 20 miles above the Grand rapid, as indicated on the Geological Survey and other maps, consists of the Driftwood, the Major, and the Wheel rapids; individually, these are of little importance, the Driftwood having a descent of two or three feet in a quarter of a mile, the Major, a descent of six feet in one-half mile, and the Wheel, three feet in one-half mile.

Grand Rapid is much the most important rapid of the Athabaska river, particularly from a water-power standpoint; it is 150 miles distant from Athabaska, following the river, but only about 110 miles in a straight line. The river, at this point, is divided into two channels by an island and the difference in elevation of the water at the ends of the island is 32 feet; this descent occurs within a distance of 2,200 feet. Below the main rapid are two and a half miles of rapids and swift water, called the "Little Grand" rapid, with a total descent of 10 feet. Above the head of the main rapid is another rapid, about one-half mile long, with a descent of 12 feet. The total descent is, therefore, approxi-

mately 54 feet in less than three and one-half miles. M. C. Hendry's survey, in 1912, shows that 45 feet head can be developed: maximum continuous output, approximately 9,500 h.p.; for nine months of year 16,400 h.p. would be available.

Between Grand rapid and Brûlé rapid, are two other rapids. One of these, situated at point Brûlé, has a descent of ten feet in two miles; the other, which is about two and one-half miles above, has a descent of ten feet in one mile.

Brûlé Rapid is situated 22 miles below the Grand rapid, or six miles below Point Brûlé; it has a descent of eight feet in slightly more than one-half mile.

Boiler Rapid, 17 miles below Brûlé rapid, has a descent of 25 feet in three miles.

Middle Rapid, situated three miles below Boiler rapid, has a descent of 20 feet in one and one-half miles.

Long Rapid is situated three miles below Middle rapid. It is three miles long with a total descent of 28 feet.

Crooked Rapid, seven miles below Long rapid, is about one and one-half miles long, and has a descent of 13 feet.

Rock Rapid, one mile below the foot of Crooked rapid, is one and one-half miles long, with a descent of 12 feet.

Little Cascade Rapid is three miles below Rock rapid. It has a descent of ten feet in two miles, and includes a stretch of swift water and a succession of rapids.

Cascade Rapid is situated two miles below the Little Cascade and has a descent of seven feet in a distance of one mile.

Mountain Rapid, seven miles above McMurray, descends eight feet in about one mile. Midway between it and Cascade rapid is a series of rapids or swift waters extending over a distance of four miles and having a total descent of 15 feet.

Moberly Rapid, two miles above McMurray, is unimportant; the descent is only two or three feet in a quarter of a mile.

The foregoing description covers the portion of the river below the mouth of the Lesser Slave river. Above this point the following power sites are to be noted:

Athabaska Fall, where a head of 20 feet could be developed to give 637 h.p. during the open season.

Tp. 56, R. XXI, west of fifth meridian, where a head of 42 feet would give 9,550 h.p. during the open season.

Tp. 58, R. XXI, west of fifth meridian, where a head of 80 feet would give 18,000 h.p. during the open season.

DISCHARGE OF THE ATHABASKA RIVER

Date	Location	Discharge sec. feet
1911		
Sept. 18	Athabaska	28,783
1912		
Sept. 18	Sec. 8, tp. 51, rge. 25, w. of 5	7,334
1913		
Feb. 27	Athabaska	2,820
Mar. 29	Athabaska	2,368
Dec. 5-6	Athabaska	4,313
Dec. 23-24	Athabaska	4,077

Regular gauging stations have been established on this river near Jasper and at Athabaska by the Irrigation branch of the Department of the Interior. The following are summaries of monthly discharges at these stations since their establishment:

DISCHARGE OF THE ATHABASKA RIVER, NEAR JASPER
(Drainage area, 1,600 square miles.)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1913				
July (1-22)	11,632	4,450	7,268	4.540
August (5-31)	13,428	5,900	8,604	5.387
September	7,390	2,422	4,114	2.571
October	3,240	1,110	1,748	1.092
November	1,160	650	930	.581
December	807	351	552	.345
1914				
January	557	354	476	.298
February	380	243	556	.348
March	388	271	334	.209
April	853	340	574	.359
May	5,200	820	2,379	1.488
June	13,440	3,904	8,242	5.151
July	16,320	6,924	11,366	7.104
August	9,780	4,670	6,512	4.070
September	4,876	1,908	3,191	1.994
October	3,775	1,124	1,897	1.186
November	1,212	660	857	.535
December	715	480	540	.338
1915				
January	563	494	536	.335
February	490	438	463	.289
March	437	402	423	.264
April	1,430	440	752	.470
May	6,360	1,135	3,955	2.472
June	19,620	4,200	7,960	4.975
July	13,070	7,230	10,055	6.284
August	16,220	9,900	12,043	7.527
September	8,160	1,675	3,430	2.144
October	2,130	1,279	1,592	.995
November	1,500	620	880	.550
December	853	422	717	.448

MONTHLY DISCHARGE OF THE ATHABASKA RIVER, AT ATHABASKA

(Drainage area, 29,200 square miles.)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1914				
January	3,500*	2,900*	3,200*	.110*
February	3,150*	2,630*	2,902*	.099*
March	3,300*	3,000*	3,161*	.108*
April	12,300	3,175	4,615	.158
May	18,450	11,160	13,216	.453
June	108,640	11,340	56,223	1.925
July	55,656	23,525	41,280	1.414
August	23,525	16,040	19,358	.663
September	17,800	11,530	13,832	.474
October	16,900	8,700	12,572	.431
1915				
January	3,890	3,330	3,669	.126
February	3,640	2,860	3,232	.111
March	6,800	3,080	4,044	.138
April	15,600	7,725	11,616	.398
May	20,450	7,887	13,112	.449
June	97,620	18,395	40,510	1.387
July	92,080	37,100	58,539	2.004
August	37,030	23,840	29,365	1.006
September	22,300	10,590	15,007	.514
October	10,415	7,757	8,929	.306
November	8,180	4,000	5,460	.187
December	4,010	2,890	3,340	.114

*Discharges for January, February and March estimated, as no gauge heights were obtained until March 17.

Clearwater River

The Clearwater is one of the tributaries of the Athabaska river, entering it at McMurray. It winds through a valley which has received very favourable notice from many travellers and explorers. Below Methy portage the stream varies from 200 to 400 feet in width. It is fairly rapid and numerous sandbars have formed in its bed. The valley is from one-half mile to three miles wide, and, in the greater part, contains good soil. The upper region is very heavily wooded with large timber. On the slopes of the valley, which are from 200 to 600 feet long and rather steep, the timber is chiefly poplar, with some spruce; when the bench land is reached, large, open hay meadows are frequently seen.

Important Water-powers

Five rapids or falls of importance occur on this river, Whitemud fall offering exceptional natural advantages for water-power development. The following is a short description of these rapids, taken in the order in

which they are encountered in ascending the river from the mouth; other minor rapids, also, are included:

From two and one-half miles below to one-half mile above the mouth of the Christina river, the Clearwater comprises a series of swift waters and small rapids; the approximate descent of these is four feet per mile. Five miles below High-hill river, a small rapid, 500 feet long, descends about three feet.

Beginning immediately below the mouth of High-hill river and extending for one-half mile downstream, small rapids and swift-waters make a total descent of about five feet. Five miles above the High-hill, is a stretch of one mile of swift water having an additional descent of five feet. Just below the Cascade rapid is another stretch of swift-water a quarter of a mile in length, with a descent of three feet.

Cascade Rapid, situated about 24 miles below Methy portage, has a descent of 16 feet within one mile. The distance by the portage is only two-thirds of a mile. The lower portion of the rapid is 400 feet wide, with low banks; the upper portion narrows to 200 feet and has high, rocky banks.

Le Bon Rapid has a descent of 31 feet. It is situated one mile above the Cascade rapid, and is one and one-half miles long, following the river, but only one mile over the portage road. The river varies in width from 200 to 400 feet and the banks are low on both sides, except at a point half-way down the rapid, where the rocky banks are 40 feet high. There are five islands at this rapid.

One-half mile above Le Bon rapid a small rapid, 200 feet long, descends two feet.

Big Stone Rapid, one mile above Le Bon, has a descent of 6.5 feet in a third of a mile. The banks are low and the river is 300 feet wide.

Aux Pins Rapid, three miles above Big Stone rapid, has a descent of 21 feet; following the river it is about three-quarters of a mile in length but only one-half mile by the portage road. The river here flows between cañon-like banks 150 feet high, and the course is slightly sinuous; four rocky islands occur in this rapid.

A small rapid, situated one-half mile above the Aux Pins, has a descent of two feet in 300 feet.

Natural Power Development Site

Whitemud Fall is about four miles above the Aux Pins rapid, and the same distance below the point where the river crosses the boundary between Alberta and Saskatchewan. The descent is 40·6 feet in a distance of a quarter of a mile. This section of the river has limestone banks, from 50 to 75 feet high, while an island in midstream affords splendid conditions for power development, as the wider channel is not over 200 feet wide. The natural head of 40·6 feet could easily be increased to 50 feet by submerging small rapids above.

The discharge of the river immediately below the Cascade rapid was 2,241 cubic feet per second, in September, 1912; the stream was 363 feet wide, the maximum depth seven feet, and the greatest mean velocity in any one section 1·82 feet per second.

Lesser Slave River

Lesser Slave river drains Lesser Slave lake and falls into the Athabaska river 70 miles above Athabaska. Originally, it was the chief means of access to the Peace River valley. In 1911, about 1,000 tons of freight, in addition to passengers, were carried over this route, and the traffic had increased enormously before the Edmonton, Dunvegan and British Columbia railway was opened.

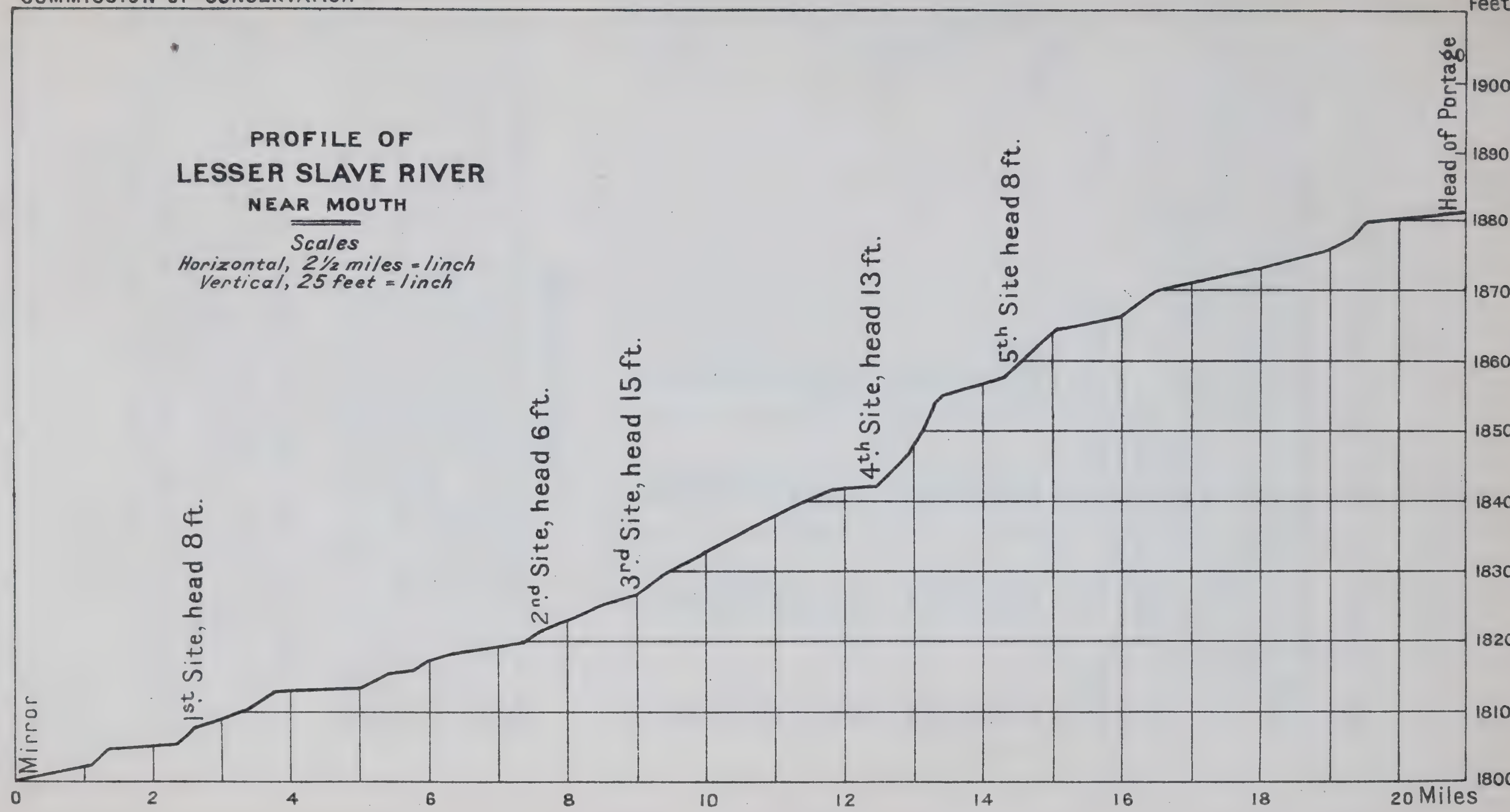
The Lesser Slave river, from its mouth to a point situated 19 miles upstream, or 16 miles overland, is very sinuous and forms a continuous series of small rapids; the total descent is approximately 80 feet. Some of these rapids could doubtless be used for water-power development. The Dominion Government has endeavoured to improve the navigation of this portion of the river by building wing dams at numerous points; as this has not had the desired effect, additional surveys have been made with the purpose of improving navigation in a more efficient manner. Discharges taken at Mirror in 1914 gave 2,905 sec.-ft. on Sept. 18, and 4,342 sec.-ft. on Oct. 9.

DISCHARGE OF LESSER SLAVE RIVER AT SAWRIDGE, ALTA.
(Drainage area, 6,520 square miles)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1915				
May (20-31)	2,060	1,942	2,050	.314
June	2,380	2,060	2,197	.337
July	2,315	2,060	2,182	.335
August	2,250	1,782	2,065	.317
September	2,380	1,474	1,771	.272
October	1,734	1,418	1,521	.233
November	1,536	600	942	.144
December	857	565	669	.103

Pembina River

The Pembina river, one of the upper tributaries of the Athabaska, is approximately eighty yards wide and is, ordinarily, quite shallow and easily fordable. In the spring or during a rainy season the depth is sufficient to compel horses to swim. The valley is from 250 to 300 feet below the level of the surrounding country, and gives evidence of greater erosion than would be expected from the present volume of water. Discharge measurements in 1913 at S.W. 20-53-7-5 gave the following: February 20, 53 second feet; March 14, 70; November 19, 77.


PROFILE OF
LESSER SLAVE RIVER
NEAR MOUTH
Scales
Horizontal, 2½ miles = 1 inch
Vertical, 25 feet = 1 inch
Feet
1900
1890
1880
1870
1860
1850
1840
1830
1820
1810
1800
Mirror
1st Site, head 8 ft.
2nd Site, head 6 ft.
3rd Site, head 15 ft.
4th Site, head 13 ft.
5th Site head 8 ft.
Head of Portage
0
2
4
6
8
10
12
14
16
18
20 Miles

A gauging station was established on this river near Entwistle by the Irrigation branch of the Department of the Interior. The following is a summary of monthly discharges at this station for 1914:

DISCHARGE OF THE PEMBINA RIVER, NEAR ENTWISTLE, ALTA.
(Drainage area, 1,858 square miles.)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1914				
May (8-31)	2,220	360	1,177	.633
June	17,260	270	4,348	2.340
July	2,730	610	1,554	.836
August	540	270	311	.167
September	450	210	317	.171
October	360	240	277	.149
November	240	110	150	.081
December	108	36	59	.032
1915				
January	59	17	40	.022
February	38	9	29	.016
March	117	39	66	.036
April	983	126	510	.274
May	1,265	230	418	.225
June	10,494	1,780	4,266	2.300
July	8,252	1,825	4,157	2.237
August	1,720	465	900	.484
September	518	377	428	.230
October	518	377	474	.255
November	417	86	218	.117
December	85	61	78	.042

McLeod River

In its headwaters the McLeod, a mountain tributary of the Athabaska, flows over a bed of gravel and stones, with uniform and rather steep grade, but without concentrated falls. The channel is nowhere worn down to bed-rock. Where it crosses range XVII the river is 110 yards wide and, ordinarily, not more than two feet deep at the ford. Although the volume of water is greater than that of the Pembina, the valley is comparatively shallow, being only from 90 to 100 feet deep.

At a point on the McLeod river, three miles from Edson, immediately above the mouth of Moose creek, a possible power site is reported. The site is at a rapid one-third of a mile in length with a descent of 16 feet. A total head of 30 feet could be obtained by a dam placed at the head of the rapid, and, with an estimated minimum flow of 100 second-feet, over 330 theoretical h.p. could be obtained.

DISCHARGE OF THE McLEOD RIVER

Date	Locality	Discharge sec.-feet
1912		
Sept. 16	Just below Beaver Dam river	471
1913		
Feb. 17	33-52-17-5	96
Feb. 18	N.W. 5-52-18-5	59
Mar. 13	"	95
Apr. 12	"	304
May 22	"	1,840
June 10	"	1,666
July 5	"	1,731
July 12	"	947
July 22	"	653
Aug. 10	"	1,670
Aug. 28	"	572
Sept. 11	"	361
Oct. 9	"	267
Sept. 26	Near Thornton	550
Oct. 10	"	493
Oct. 22	"	448
Nov. 7	"	440
Nov. 20	"	237
Dec. 17	"	167

A gauging station was established on this river near Thornton by the Irrigation branch of the Department of the Interior. The following is a summary of monthly discharges for 1914:

MONTHLY DISCHARGE OF THE McLEOD RIVER, NEAR THORNTON
(Drainage area, 2,507 square miles)

Month	Discharge in second-feet			
	Maximum	Minimum	Mean	Per square mile
1914				
May (18-31)	1,640	790	1,365	.544
June	20,584	720	7,453	2.973
July	5,220	790	2,144	.855
August	1,010	480	624	.249
September	1,450	480	709	.283
October	720	430	571	.228
November	600	208	363	.145
December	280	75	193	.077
1915				
January	150	98	122	.049
February	142	81	108	.043
March	235	81	131	.052
April	788	261	556	.222
May	1,820	560	1,131	.451
June	33,688	1,930	7,198	2.871
July	27,220	2,860	9,720	3.877
August	4,230	1,150	1,843	.735
September	1,420	830	1,063	.424
October	1,510	830	1,050	.419
November	760	225	492	.196
December	200	162	170	.068

CHAPTER XIII

Eastern Tributaries of Lake Athabaska

Black River

Black river flows from Wollaston lake to lake Athabaska, in a general north-westerly direction. Between Hatchet and Kosdaw lakes, in its upper part, it is broken by several rapids, with single descents as great as 20 feet.

Farther downstream is Thompson rapid, one of the heaviest rapids in the upper portion of the river; its banks, toward the foot, are low, while the upper section has to be passed by a short portage, 35 yards long, across a point on the north side. Above the portage, almost to the top of the rapid, the banks are from ten to fifteen feet high, and consist of flat-lying sandstone, generally cut away beneath by the water. The total fall in the rapid is approximately 30 feet.

Manitou Fall

Manitou fall, lower down, was so named by the Indians because the water in one of its channels disappears under the rock for a short distance. Two streams tumble over the face of a rocky sandstone ledge into a narrow channel about 25 feet wide; thence part of the water rushes to the left in an open channel, while the remainder flows for about 20 yards under the rock; both streams fall into a wide, shallow, rocky basin. The fall is 15 feet in height and is passed by means of a portage 120 yards long, on the south side.

Brink rapid, one mile long, has a total descent of 25 feet, where the water rushes over ledges of sandstone. The banks consist of low, sandstone cliffs and a ridge of sandstone extends along the north side of the river. From this rapid, as far as the head of Hawkrock rapid, is a stretch of one mile and a quarter of quiet water, with banks of sandstone 35 feet high. Hawkrock rapid, just above the mouth of Hawkrock river, has a fall of from eight to ten feet. In its upper part the banks of reddish sandstone are ten feet in height.

North rapid, one mile in length, has a total descent of about 15 feet. Like the preceding rapids, it is fairly deep at the head but wide and shallow at the foot. The bed of the rapid is filled with boulders.

At the head of Middle lake is a long chain of rapids and falls, with a total descent of 120 feet within a distance of three and one-half miles. The lowest, Elizabeth fall, alone comprises 80 feet of the

total descent. The river here forms a turbulent rapid one mile in length, broken by heavy cascades and falls from eight to ten feet in height. The north bank, thickly wooded with black spruce and birch, rises gradually toward distant green hills; the slope is underlain by reddish gneiss. The south side of the valley is composed of abrupt, sandstone cliffs, often vertical, rising to a height of 100 feet above the water. Rounded bosses of gneiss also rise in the bends of the south bank, while wooded islands and jagged, granite rocks constantly impede and obstruct the foaming torrent.

Immediately below Middle lake a series of strong rapids has a total descent of about 160 feet. The lowest rapid is a beautiful cascade, where the water tumbles over a ledge and then rushes in two narrow gorges past a rugged, rocky island. The portage along these rapids is 1·9 miles long.

Cree River

Where Cree river, a tributary of Black lake, emerges from the north end of Cree lake, it is 200 yards wide, with sandy bottom and low banks wooded with small Banksian pine and spruce. It soon becomes very rapid, with a current of from six to eight miles per hour, flowing over a bed of sandstone fragments. Six miles below the lake a long rapid, known as Hawk rapid, has a total descent of from 30 to 40 feet within a distance of two miles.

For 20 miles, strong rapids succeed each other in an almost continuous series. The river first becomes narrow and swift, often with a current of ten or twelve miles per hour; it then expands gradually into a shallow stream flowing over a wide bed of gravel and boulders.

In approximate latitude 58° 28′ another heavy rapid, three miles in length, has a fall of about 40 feet. Hills of boulders, varying in height from 100 to 150 feet, rise on each side, and the bed of the stream is formed of boulders that have fallen from the sides. The upper portion of the rapid is deep and narrow, while the lower stretches are wide and shallow.

Geikie River

Geikie river is the principal tributary of Wollaston lake. It rises in several small lakes, near the source of Foster river, and flows northeastward through a drift-covered country, between low, sparsely-wooded banks. For long stretches it is straight and sluggish, having the appearance of a wide, quiet river or chain of long, narrow lakes.

From a point situated immediately below the mouth of the Poorfish river to Big Sandy lake in the upper part, these quiet stretches are broken by numerous rapids flowing over beds of boulders and descending as much as 45 feet.

CHAPTER XIV

Peace River

Peace river, formed by the junction of the Finlay and Parsnip, two mountain rivers, is the largest and longest of the tributaries of the Mackenzie. It rises in and drains a great area west of the Rocky mountains; continuing eastward, it intersects the axis of that range and drains the country bordering its eastern slopes, through four degrees of latitude. Its length, from the confluence of the Finlay and Parsnip rivers to the point at which it unites with the waters flowing from lake Athabaska to form Slave river, is 780 miles, but, measured from Summit lake, the source of its principal branch, is approximately 905 miles.

Peace River Cañon

Peace River cañon is situated in British Columbia, just outside of the western boundary of the Peace River Block. The descent of the water in the cañon is fairly uniform, except near the head, where there is a fall of approximately 25 feet in one-half mile. This latter descent is concentrated at two chutes over ledges; one is situated at the head of the cañon and the other one-half mile below, with rapids intervening.

The narrowest point in the cañon occurs at its head, where the distance from bank to bank is only 200 feet. The total descent in the water from the head to the foot of the cañon, as obtained by aneroid barometer readings, was found to be 225 feet.

The total length from head to foot, following the water, is 18·25 miles. The portage trail, which is 11 miles long, follows very closely a straight line from the head to the foot of the cañon. The upper section of this trail passes between two hills, Portage mountain on the south and Bulls Head mountain on the north side, and, except over a distance of about one mile at each end, the trail has an elevation varying between 800 and 1,000 feet above the water level at the lower end of the cañon.

Deep and Picturesque Valley

Between Smoky River forks and the mouth of Battle river, a distance of 108 miles, the general course of Peace river is northerly. Its average width in this distance is approximately 400 yards but it expands occasionally to nearly twice this distance. The current has a uniform rate of about

four miles per hour. The deep valley is, in portions, very picturesque. It is about two miles wide and, at the mouth of Smoky river, the water is not less than 700 feet below the level of the plateau. Toward the north the valley becomes gradually shallow; at Battle river its bottom is only 600 feet below the plateau. The banks are often scarped and, where composed of sandstone, are precipitous.

Below Battle river, as far as the Vermilion fall and rapids, a distance of nearly 200 miles, Peace river is without striking features; the current is less rapid, having a uniform rate of about three miles per hour. The valley decreases in depth to approximately 100 feet, and the sandstone cliffs, which lend variety to the upper stretches of the river, disappear. They are replaced by grassy and wooded slopes, or by the sombre, clay shales of the cretaceous. Islands are more numerous, while the bars are composed of sand instead of gravel.

Vermilion Rapids and Chute.—Below Fort Vermilion, Peace river flows in an easterly direction for approximately fifty miles to the Vermilion fall and rapids. Vermilion fall, like the Cascade rapids on the Athabaska, is caused by the river falling over a low, limestone ledge.

This fall is the first obstruction to navigation encountered in descending the Peace river from the Peace River cañon. First the rapids occur, extending over a distance of one-half mile, where the river makes a slight bend; then comes swift water for three-quarters of a mile, succeeded by rapids again for one-half mile and, finally, the sheer drop of the chute. A reflecting level showed the descent in the first rapids to be 10.1 feet. The banks of the river here are from 20 to 30 feet high but, just above the rapids, are much lower. The descent in the other rapid, which is situated immediately above the chute, was found to be 4.4 feet and, in the chute itself, 12.1 feet. Thus, the total descent of the rapids and chute is 26.6 feet within a distance of one and three-quarter miles. The banks in this part are 50 feet high, consisting of hard limestone. The water was rather low when the levels were taken, but it usually falls another two feet in late autumn. The river varies in width at the rapids and chute from one-half to one mile, and the widest point is near the chute.

Boyer or Little Rapids.—These rapids are situated about 115 miles below the Vermilion chute. They consist of four pitches, extending over a distance of five miles and separated by slack water. The rapids become merely swift water when the river is at a high stage. When the water is low, the rapids are quite noticeable but, even then, the greatest descent in any one pitch is only eight feet

PEACE RIVER—HEAD OF PEACE RIVER CAÑON

SLAVE RIVER—ONE OF THE FORT SMITH RAPIDS

in three-quarters of a mile, occurring in the pitch farthest downstream. These rapids are of little value from a water-power standpoint.

Mr. F. D. Wilson, late post manager for the Hudson's Bay Company at Fort Vermilion, kindly compiled the table and furnished the following interesting information respecting the opening and closing of the Peace River navigation:

OPENING AND CLOSING OF NAVIGATION ON PEACE RIVER, AT FORT VERMILION

Year	Ice began to move	First crossing in boats	Ice began to drift	First crossing on ice
1890	May 4	May 8	Nov. 16	Nov. 30
1891	Apr. 23	May 1	Oct. 29	Nov. 12
1892	May 11	May 15	Nov. 4	Nov. 8
1893	May 3	May 10	Oct. 31	Nov. 4
1894	Apr. 29	May 6	Nov. 1	Nov. 10
1895	Apr. 25	Apr. 29	Nov. 7	Nov. 15
1896	May 2	May 5	Nov. 7	Nov. 10
1897	Apr. 20	Apr. 26	Nov. 10	Nov. 13
1898	Apr. 23	Apr. 27	Oct. 27	Nov. 1
1899	May 5	May 10	Oct. 20	Nov. 12
1900	Apr. 14	Apr. 20	Nov. 4	Nov. 15
1901	Apr. 26	May 3	Nov. 2	Nov. 6
1902	May 1	May 6	Nov. 4	Nov. 8
1903	May 3	May 13	Nov. 11	Nov. 19
1904	Apr. 17	Apr. 24	Nov. 16	Nov. 30
1905	Apr. 27	Apr. 30	Oct. 23	Nov. 1
1906	Apr. 20	Apr. 22	Nov. 10	Nov. 16
1907	May 6	May 13	Nov. 8	Nov. 13
1908	Apr. 30	May 5	Oct. 28	Nov. 2
1909	May 20	May 22	Nov. 5	Nov. 13
1910	Apr. 25	Apr. 28	Nov. 1	Nov. 9
1911	Apr. 29	May 3	Oct. 31	Nov. 9
1912	Apr. 29	May 1		

MONTHLY DISCHARGE OF PEACE RIVER AT PEACE RIVER CROSSING

Month	Discharge in second-feet		
	Maximum	Minimum	Mean
1915			
May (28-31)	165,350	156,900	161,512
June	183,400	129,400	144,236
July	338,850	102,700	158,518
August	95,550	43,800	63,979
September	43,800	23,700	31,902
October	42,960	20,950	27,468
November	42,600	11,160	18,301
December	11,140	10,250	10,786

CHAPTER XV

Slave River and Tributaries of Mackenzie River

The Slave river flows from lake Athabaska to Great Slave lake and is virtually the upper portion of the Mackenzie. It carries the waters of the mighty Peace river, of the Athabaska river and of other tributaries of lake Athabaska. It flows slightly west of north, with a total length of approximately 290 miles. For nearly 100 miles below lake Athabaska, it is easily navigable, but its course is then interrupted by a series of rapids, generally known as Fort Smith rapids, which are caused by a gneissic spur from the Laurentian district to the east.

The rapids, five in number, occur between Smith Landing and Fort Smith. The following is a description of each, taken in the order in which they are encountered in descending the river from Smith Landing:

Cassette Rapid is situated two miles below Smith Landing, where the river contains numerous small, rocky islands. Levels taken in the eastern channel show a descent of 27 feet. The total length of the rapids in this channel is one and a half miles, but would not be more than one mile measured along the centre of the river. The banks are high and rocky.

Second Rapid.—The river here has a wide main channel on the west side, where the descent is concentrated in one chute extending the whole width of this channel. On the east side, there are several small, rocky islands. Levels taken of the different falls in one of the channels between these islands show a total descent of 37·4 feet; between the different pitches are swift waters with a fall of possibly five feet, thus giving a total descent of approximately 42 feet. The total length of the channel between the islands is about two miles, but, as stated above, in the main channel most of the descent is concentrated in one fall.

Mountain Rapid, flowing around a point which projects from the west bank of the river, has a descent of 25 feet. Following the river, the rapid extends for about one mile, but across the point (along the portage path) the distance is only 200 yards. Opposite the point, the river is one-half mile wide, and farther down-

stream, three-quarters of a mile. The rocky banks are from 50 to 100 feet high.

Pelican Rapid is a continuous stretch of rapids, without any considerable concentrated fall. It extends over a distance of three miles, or practically from the foot of Mountain rapid to the head of Drowned rapid. The descent in this rapid is about 10 feet.

Drowned Rapid is one-half mile long, with a descent of 13 feet. The stream, three-quarters of a mile wide, has rocky banks 100 feet high on the west side; on the east side, numerous islands occur and the banks are only from 25 to 50 feet high.

The distance from the head of Cassette rapid to the foot of Drowned rapid is 15 miles and the total descent, including swift waters between the five rapids above mentioned, which are not included in the figures given, is about 135 feet.

Below the rapids, the banks, which, at first, are about 100 feet high and terraced in places, become lower as one descends the river. Eighteen miles below Fort Smith is the mouth of the Salt river, below which the stream presents few features of interest. Its average width is about one-half mile, but it frequently expands around islands to twice this width. On both sides are level plains which extend as far as the eye can reach and support extensive forests of white spruce and Banksian pine, mingled with larch and rough-barked and smooth-barked poplar. Sandy beaches, bars and islands occur in this part of the river; these are constantly shifting, being built up and removed by the spring freshets.

Lockhart River

The Lockhart is a short stream connecting Artillery lake with the eastern arm of Great Slave lake. It is only 24 miles in length but the descent in it is very steep. The most important fall on it is Parry fall with a descent of 85 feet but there are five others with descents ranging up to 50 feet. The total descent in this short river has been estimated at 668 feet which gives it an outstanding value as a water-power stream.

Hay River

Hay river rises near the headwaters of the Fort Nelson river and flows in a north-easterly direction for 300 miles to Great Slave lake. Grassy and partly wooded plains extend northward from Peace river and skirt its southern shores, but do not cross it. This river may be regarded as practically the northern limit of the prairie

country. Hay river, like Slave river, enters Great Slave lake by several channels at the extremity of a point formed by the deposition of silt.

Its banks are low and grassy and the country on both sides is heavily wooded. Ascending the river, the general elevation of the country increases, the valley becomes higher and wider, and bordering flats make their appearance. The current at the mouth is gentle but, as the river is ascended, increases in rapidity and breaks into ripples on the bars. The valley then contracts into a gorge and its high walls, buttressed below by an embankment of fallen fragments, appear to overhang the stream; the latter, reduced in width to 100 feet, dashes turbulently along the boulder-filled channel.

The gorge suddenly ceases at Alexandra fall and the river plunges over the hard limestone band, through which the gorge is cut, with a sheer descent of 85 feet. This exceedingly picturesque fall presents a clear, unbroken sheet of falling water. From its base the river flows along rapidly for about one mile to a second fall of about 50 feet, below which are three miles of rapids. At the lower fall, the cliff is broken down near the centre and the descent of the water is interrupted by projecting ledges. Above the fall the valley is almost imperceptible; the stream has failed to produce more than a feeble impression on the hard limestone beds which floor the surrounding country.

Liard River

The Liard river, one of the principal tributaries of the Mackenzie, has its source west of the Rocky mountains. One of its branches reaches to within 150 miles of the sea and drains the eastern portion of the broken country lying between the Rockies and the Coast range. Its branches extend through four degrees of latitude, from 58° N. to 62° N., and interlock with those of the Yukon, Stikine, Skeena, and Peace rivers. In its upper part, it divides at intervals into three nearly equal streams, the Dease river in British Columbia, the Frances river, and the branch which retains the common name. Rising in the elevated country west of the Rockies, the Liard falls rapidly toward the east. Between the mouth of the Dease and the Mackenzie it descends about 1,650 feet, and is characterized by impetuous currents, dangerous rapids and narrow, whirlpool-filled cañons. The descent is greatest and the rapids most numerous among and near the Rocky mountains. After leaving the foothills the stream is nearly free from interruptions as far as the junction with the Mackenzie, where a series of strong rapids occurs.

Varying Characteristics of River Bed

Above the Lower* cañon, the current is swift, averaging about four miles per hour and greatly exceeding this rate in many reaches. The stream, which is wide and shallow, becomes in places a complete maze of islands and gravelly, half-submerged bars.

The Lower cañon is six miles above the mouth of the Dease. The full height of the plateau, through which the river here cuts, is about 500 feet, but banks of this height seldom abut directly on the river. The cañon is three miles in length, and, at high water, it is said to be necessary to portage the entire distance.

Immediately above the mouth of the Dease, the Liard is 840 feet in width. Below the Dease it varies in width from 250 to 400 yards, but expands in places to more than half a mile; it has a current of four miles and a half per hour. It divides occasionally into a number of channels, enclosing low, alluvial islands, usually well wooded.

The rough water at Cranberry portage, four miles above Turnagain river, has a total length of one mile and a half, but there is a reach of comparatively undisturbed water about halfway down. The upper part of the rapid is exceedingly turbulent, as the bed of the river is filled with huge, angular masses of rock, against which the current dashes violently.

Rough and Irregular Channel

Two miles below the Turnagain river is the Mountain Portage rapid, one of the most dangerous rapids in the river. The stream here falls over a band of shales irregularly hardened by a system of dykes and worn into a succession of ridges and hollows; the roughened surface thus produced throws the hurrying stream into an indescribable turmoil.

The rapids at Brûlé portage, three miles below Coal river, is two miles long, and is caused by numerous limestone blocks and small islands obstructing the channel. At the lower end, the river is narrowly confined by high, perpendicular cliffs.

From Brûlé portage, no obstacles to navigation occur until the Devil portage is reached. This stretch of the river is wide and filled with low islands and bars.

At Devil rapid, eight miles below Trout river, the Liard makes a great bend to the northeast through a succession of rapids and cañons. At the elbow of the bend, a large fall is situated. At the foot of the curve, the river is confined to extremely narrow limits, being scarcely 150 feet wide, and, as fully a third of this width is occupied by shore eddies, its bed must be eroded to a very great depth.

* The designation "Lower," given to this cañon, is evidently relative to the Upper and Middle cañons on the Frances river.

Immediately below the contracted section is a large eddy, where the river expands suddenly to more than half a mile in width. The distance travelled by portage to avoid these rapids is three and three-quarter miles.

Below Devil portage, for 30 or 40 miles, the river flows through the Grand cañon, comprising a series of short cañons separated by expanded basins filled with eddying currents.

Rapid of the Drowned

Twenty-five miles below Devil rapid, the river bends to the north, and, dashing against the cliffs which form the left bank, is deflected again to the east through the rapid of the Drowned. This is one of the most dangerous places on the river; the water plunges with its whole force over a ledge of rock, which curves outward and downward from the left bank, into a boiling *chaudière* behind.

Below the rapid of the Drowned is a long reach, with very swift current; the river is then confined by hard, sandstone banks through a narrow gap in which it forces a stormy passage. In the next four miles the stream, narrowly contracted, flows through five cañons and falls over a number of riffles.

Three miles of rapid current are encountered before reaching Hell-gate, so named because it is the lower entrance to the turbulent section of the river just described.

Emerging from Hell-gate cañon, the river dilates and is bordered by large eddies. Below these, it flows swiftly around a large island into a cañon-like reach one mile long. The stream here is narrowed to about 150 yards in width, flowing quietly between vertical banks 300 feet high. This cañon is the lowest on the river, and thence the stream has an uninterrupted flow. No obstacles to navigation present themselves until a point 40 miles from the mouth is reached, from which, for a distance of 25 miles down, the stream is bordered by steep, scarped banks from 200 to 400 feet in height, giving the appearance of a wide cañon. The current in this entire reach is exceedingly swift, and, for nearly ten miles, breaks over a succession of strong rapids.

Navigable in Parts

With respect to navigation on the Liard, it may be stated generally that, above the rapids just referred to, which a small steamboat could possibly overcome by using a line, the river is easily navigable as far as Fort Liard, and thence, up the west branch, as far as Hell-gate. Above Hell-gate, navigation is exceedingly difficult and dangerous even with small boats, owing to the numerous rapids and cañons. The Fort Nelson, or east branch of the Liard, is reported to be navigable by small steamers for 100 miles or more above its mouth.

Frances River

The Frances river is a tributary of the Liard, flowing into the latter from the north. In ascending the river, the general direction of the Frances, for nine miles from its mouth, is north-northwest. It then bends to the northeast and, in four miles, the lower end of the Middle cañon is reached. For the first few miles above its mouth, the Frances is extremely tortuous, so much so that the actual course of the river to the foot of the cañon covers 22 miles, while the distance in a straight line is only 11 miles.

The Middle cañon is three miles in length; the river is hemmed in by broken, rocky cliffs, from 200 to 300 feet in height, for the greater part of this distance. The total fall in the cañon is estimated at approximately 30 feet. Above the Middle cañon, the general course of the river is again north-northwestward for a distance of 12 miles. Most of this section is bordered by low land on both sides.

Fifteen miles farther up, the course changes to northeast, cutting across the Tsesiu range. The stream is moderately swift throughout and, in one place called the False cañon, is bordered on both sides by low, rocky banks, although no rapids are encountered.

Fifteen miles above False cañon, the river turns abruptly to the west for four miles, one mile and a quarter of which consists of a series of rapids; these are rocky and strong, with a total fall of about 30 feet. The banks rise steeply from the river to heights of from 100 to 200 feet, although the rocky cliffs along the water rarely exceed 50 feet in height. This section, named the Upper cañon, is the last serious impediment to the navigation of the river.

Gravel River

Gravel river rises on the eastern slope of the Mackenzie mountains which form the divide between the Yukon and Mackenzie basins. From its source, to its exit from the mountains, it scours bed-rock in a continuous rapid, or flows over boulders which are too large to be carried.

It is an extremely swift river throughout its whole length, the velocity being maintained to a great extent even in its lower portion. At the mouth, its waters rush along their original direction for quite a distance across the Mackenzie. While to travel down the river is a fairly easy but dangerous task, the ascent is almost impossible even in a canoe.

The descent in the river from the confluence of the Twitya river to the mouth, a distance of some 125 miles, is estimated at 1,350 feet

or almost 11 feet per mile. The grade is slightly steeper after entering the mountains but otherwise very uniformly distributed without any concentrated falls or rapids. The lowest cañon on the river is some eighty-five miles from the mouth. The conditions at this cañon and at practically all the others on the river are not favourable for power development. The descent is generally the same as in other places while the banks on the portions of the river immediately above and below the cañons are low.

From Twitya river to Sekwi cañon, a distance of seventy miles, the descent in the river is also uniformly distributed, averaging approximately 12 feet per mile, without any falls or decided rapids. Between Sekwi cañon and the headwaters there is a total descent of approximately 2,085 feet fairly uniformly distributed over a distance of forty-five miles. The only concentrated descent in this portion occurs at Cañon fall, some thirty miles above Sekwi cañon, the water descending 10 feet in a vertical fall.

The average temperature on both sides of the Mackenzie mountains is very much alike, but the western slopes, of higher elevation and exposed to the prevailing winds, have a comparatively high precipitation, and periods of high winds, while the eastern slopes, being on the lee side, receive a small precipitation, and immunity from high winds.

A rough measurement of the Gravel river above its mouth, taken on July 19, 1908, gave a width of 700 feet, a middle depth of 8 feet, and a surface velocity of five miles an hour; the approximate discharge being 25,000 cubic feet per second. It is probable that the river shrinks greatly in volume by the end of August, as the snow is then almost completely gone from the mountains, and the rainfall is very light.

CHAPTER XVI

Churchill River and Tributaries

Churchill river, measured from the source of its longest tributary, the Beaver, to Hudson bay, has a length of 1,200 miles, approximately. It comprises a long series of very irregular lakes, connected by short and usually rapid reaches. The low banks are thickly wooded with spruce and poplar. Some of the rapids are due to rocky barriers, while others flow over boulders and between banks of till, such as underlies much of the surrounding country. For a considerable part of its course, the river appears to flow near the line of contact of the Archæan and overlying sedimentary rocks, although the topography is modified by the occurrence of prominent glacial features.

The absence of a valley, even where the channel might be eroded easily, and the presence of numerous lakes and rapids, show that the river is very new, geologically speaking.

Many Rapids along the River

For a distance of several miles above Pelican rapid, the river flows from the northwest with a moderate current; it passes between low, sandy banks overhung with willows, beyond which the country is wooded with poplar.

Pelican rapid is a cascade, falling about eight feet over a granite ledge. The north bank, below the fall, is a terrace of sand and boulders, 20 feet high.

The Upper and Middle Knee rapids flow around a long projection of red gneiss. The Lower Knee rapid is long and shallow. It flows at first over a ledge of coarse, red gneiss, and then over a bed of boulders. The north bank is a cliff, 30 feet or more in height, composed of light gray, sandy till, containing many boulders, and rising to a sandy plain or terrace.

Below the mouth of Haultain river, the Churchill flows with a strong current and traverses a wide marsh between long ridges of gneiss.

Snake rapid, flowing for one and one-half miles over a bed of boulders, connects Souris and Snake lakes. On its north side is a sandy terrace, 15 feet high, which gradually rises until it seems to merge in a low hill of sand and boulders. On the south, also, is a low hill, the

summit of which is a moderately level plain, covered with Archæan boulders.

The Middle Needle fall is caused by the river flowing over a ledge of gneiss. At the Lower Needle fall, the water descends about four feet over similar rock.

Numerous rapids and falls occur between this point and Frog portage; the greatest single descent is one of 20 feet at Otter fall. From Frog portage to the mouth of the Reindeer river, the Churchill has an average width of approximately one mile. It flows in a north-easterly direction, and its channel contains many rocky islands. The banks of this section of the Churchill are low, but on both sides the land rises gradually for a distance of from one-half to three-quarters of a mile from the water's edge, to heights varying from 100 to 400 feet.

The first fall on the Churchill, above the mouth of Reindeer river, is Kettle fall, a steep descent of 17 feet over dark-greenish schist. A portage of 130 yards is made on the north side.

At the foot of the expansion, into which Reindeer river falls, is Atik rapid, with a descent of 15 feet. Below, the river is rough for 60 miles, with many dangerous rapids, including the long Wintego rapid, at the foot of Wintego lake. Ten or twelve portages are made along this stretch, the longest being about one-half mile.

River Flows Through Series of Lakes

From the end of the rough water, at the mouth of Nemei river, to Pukkatawagan, 120 miles below, the Churchill flows for almost the whole distance through lakes, and only four short portages are necessary. Between Pukkatawagan and Southern Indian lake, a distance of approximately 130 miles, the lake expansions are larger, including Granville lake, 50 miles or more in length. In this distance four short portages lead past rapids and falls, one of which, Granville fall, above Granville lake, has a nearly vertical descent of 25 feet.

For a distance of 23 miles above the mouth of the Little Churchill, the average width of the Churchill is approximately one-third of a mile. High banks of clay occur alternately on each side. Numerous rapids exist in this section and the total descent in the above distance is about 170 feet, or an average of seven and one-half feet per mile. Rapids are numerous between the mouth of the Little Churchill and the sea, especially in the first 30 miles, and again in the neighbourhood of the angle formed by the last two stretches of the river at a distance of 40 miles from the mouth. Only one, however, necessitates a portage. This is a steep rapid, which may be called the Portage

chute, situated 28 miles below the Little Churchill. The distance over the portage is approximately 175 yards.

The total descent in the river, from the confluence with the Little Churchill to the sea, is approximately 400 feet, or an average descent of slightly more than four feet per mile to the head of tide water.

Cochrane River

In ascending Cochrane river, the channel for the first seven miles and a half is very irregular, being often broken by wooded islands. In places it is about 150 yards wide, with a current of two or three miles an hour; in other places it is much wider and with very little current, while, towards the upper end of the stretch, are two heavy rapids up which the canoe must be tracked with a tow-line. The banks are low and grassy, and low rocky points project into the water here and there. The surrounding country is low and swampy, underlain by sand and sandy till, and is wooded with small black spruce and larch. A low sandy ridge wooded with Banksian pine, extends along the east bank for a short distance. Seven miles and a half from the lake, the river falls about 20 feet over gneiss. These falls are passed by a portage 420 yards long on the east side. The portage is over a drumlin ridge of silt and boulders.

Three-quarters of a mile higher up the stream is a heavy rapid with a fall of eight feet, the water flowing over granite. It is passed by a portage 180 yards long on the west bank, over a neck of land composed largely of boulders. A mile above the portage is a swift rapid a quarter of a mile long, up which canoes must be taken with tow-lines and poles.

Two miles above this rapid the canoe-route leaves the river, which is said to be very crooked, with one bad rapid, the total distance by the river being about 17 miles.

For the next thirteen miles the current is nowhere very strong, and in the wider places is hardly apparent. The banks are either low or rise in sandy ridges. The river then flows through a number of larger and smaller lakes. Next come more portages, one of which is past a rapid having a fall of eight feet, and lake Du Brochet is reached. Above this lake, a small double lake, with rocky shores, extends for six miles, beyond which the river flows for two miles, with a strong current, between wooded sandy banks, to a narrow gap, where it cuts through a ridge of sand and gravel. A mile and a quarter above this ridge, the river flows with a rapid current, over a bed of sand and boulders in a moderately straight channel. It then makes a gradual half turn, flowing from the south-west and

numerous rapids and portages are encountered. Five miles above the upper end of these rapids the river debouches from Drifting lake, above which is a long, rapid portion to its headwater in Wollaston lake.

Reindeer River

Reindeer river, draining Reindeer lake into the Churchill river, forms one of the largest branches of the latter. The valley through which it flows is an irregular depression, following the trend of the gneiss. The banks are low and the stream rarely impinges against the rocky hills which compose the surrounding country. This stream is 70 miles long, and Reindeer lake, its source, has an area of 2,200 square miles, with an elevation above the sea of 1,150 feet. The lake has a very irregular contour, containing innumerable rocky islands; these and the rocky shores are sparsely wooded with small black spruce.

The first fall below the lake is 10 feet in height, flowing over ledges of gneiss. The portage, which crosses a narrow, rocky islet 50 yards wide, is known locally as the Rock portage. The second fall, situated between the next two lakes, is called the Whitesand rapid, on account of the cliffs of sand on the north side, opposite the portage.

The portage at Steep-hill rapid crosses a ridge of clay 35 feet in height. The water of the lake above drains toward the east, falling for 20 feet over a steep ledge situated between three islands, at the southeast corner. The sides of the valley are moderately timbered with poplar and a few small white spruce. Below Steep-hill rapid, the river makes a long bend, first to the east and then to the south, passing through a wide lake-like expansion with many islands. The stream narrows at places, in which the current is quite strong, but generally, from the Steep-hill rapid to near the mouth of the river at the Deer rapid, is wide and sluggish.

The last interruption to navigation is at Deer rapid, about two miles north of the Churchill river, where there is a fall of about five feet over a ledge of gneiss. Below this rapid is a wide, deep channel with almost imperceptible current.

Rapid River

Rapid river enters the Churchill from the south, not far below the lake expansion at Stanley mission. It is the outlet of lake La Ronge, a large oblong lake, nearly 35 miles in length, 1,225 feet above sea level and about 150 feet above its confluence with the Churchill. This short stream has a fall, or series of rapids, near the confluence with the Churchill river.

Foster River

Foster river is very similar in size to the Mudjatik river, but is a much more turbulent stream. Rising in the Foster lakes, it plunges down a series of heavy rapids, over ridges of granite and gneiss, until within a few miles of Churchill river. There it enters a country more thickly covered with drift and more densely wooded. Abandoning its direct south-westerly course, it follows a long, sweeping curve and finally empties into a northern arm of Black Bear Island lake, one of the expansions of Churchill river.

For 18 miles below the Foster lakes, the river flows in a deep valley and forms an almost continuous series of heavy rapids, rushing over a bed of boulders. Below this stretch, heavy rapids again occur, but these are due to rocky barriers across the stream; nearer the mouth, the rapids again flow over boulders. The greatest descent is that of the rapid situated farthest down the river, about six miles from its mouth; the water flows in a heavy double rapid, descending 25 feet, chiefly over a bed of boulders.

Mudjatik River

Mudjatik river rises in several small lakes and streams in the low, rocky country a short distance north of latitude 57°. It flows almost directly southward for 80 miles and empties into Churchill river, 13 miles below Ile-à-la-Crosse lake. For the greater part of the course, it flows in a shallow, winding channel between level banks of stratified sand. Rocky hills appear on both sides, but seldom close to the river. The stream is obstructed by a few rapids and most of these are caused by accumulations of boulders.

Above Grand rapid the river, which is possibly 30 feet wide, emerges from a very well-defined valley, a quarter of a mile in width.

A large rapid, flowing over rock and boulders, is situated one-quarter mile above Grand Rapid portage; this has a descent of six feet.

At Grand rapid, the water falls eight feet over a ledge of gneiss broken into two steps. A portage, 90 yards in length, passes it on the sandy flat on the east side.

Two rapids occur not far above Bear rapid, with descents of 10 feet and 12 feet. Below these the river winds through a sandy plain, to Bear rapid, a swift chute with a fall of about two feet at high water. This rapid is passed by means of a portage track, 100 yards in length, on the west bank. The rapid is probably caused by a ledge of rock crossing the channel.

Beaver River

Beaver river has its source on the Cretaceous plateau, south of lac La Biche. It flows eastward for 230 miles, and then northward for 90 miles, emptying into the south end of Ile-à-la-Crosse lake. In its course northward, from the bend to the foot of Grand rapid, it is a rapid stream, from 150 to 400 feet wide. This portion of the river has low banks, composed of stratified, alluvial clay without boulders. The surrounding country is a level plain, rising from 10 to 25 feet above the river, and well wooded with poplar. Banks of stratified sand soon begin to rise on both sides to a height of 40 or 50 feet, and the stream is broken by rapids flowing over beds of boulders.

The banks are lower near the mouth of Waterhen river, an important tributary from the west. They continue low, consisting of clay, for several miles; they then change to stratified sand, rising to a height of 80 feet.

Several small rapids occur in this stretch of the river; the following is the approximate descent in each, in the order in which they are met in descending the stream from the mouth of Cowan river:

Rapid of six feet descent, one of three feet descent, one of two feet descent; distance of five miles without rapids; rapid of two feet descent, one of four feet descent, one of two feet descent, mouth of Waterhen river; rapid of three feet descent, one of two feet descent, one of three feet descent, one of two feet descent, one of two feet descent, one of five feet descent (one mile long), one of two feet descent, one of four feet descent.

Immediately below the rapids enumerated is Grand rapid, the last on this section of the river. It consists of two pitches separated by one-half mile of slack water; the lower pitch has a descent of 16 feet within a distance of one mile, while the upper descends 10·8 feet in one-half mile, giving a total descent of 27 feet in two miles. The banks are from 15 to 50 feet high, becoming higher in the upper portion of the rapid. The river is full of boulders and has an average width of 500 feet.

The discharge of the river, taken in September, 1912, at a point five miles above the Grand rapid, was found to be 1,913 cubic feet per second; the water was unusually high for that time of the year. The width of the stream here was 346 feet, the maximum depth seven feet, and the greatest mean velocity in any one section 2·23 feet per second.

La Plonge River

La Plonge river is a small tributary, entering the Beaver in the lower part of its course; it is the outlet of a moderately large lake of the same name. On it is the most northerly developed water-power in Saskatchewan. This power site is near the mouth of the river, where a dam has been built, affording a head of about 10 feet. The power is used to operate a saw-mill and a small electric-lighting plant in connection with the Bauval mission. In the summer, nearly 40 horse-power is used by the mill but, in the winter, that amount of power is not always available.

Methy River

This river rises in Methy lake, at the southern end of the well-known Methy portage, which crosses the divide between the Churchill and Mackenzie watersheds. Methy river follows a very sinuous course in a south-easterly direction; its waters flow into Buffalo lake, and, ultimately, through the Deep river, to Ile-à-la-Crosse lake. The river is broken by several small rapids, the first of which is situated six miles below Methy lake, and has a descent of ten feet in two-thirds of a mile; the stream here is about 30 feet wide, with banks from five to ten feet high. One-half mile downstream is another small rapid, one-quarter mile in length, with a descent of three feet.

Extending for a distance of six miles above the mouth of Whitefish river is a succession of small rapids, with a total descent of approximately 40 feet. The greatest fall in a short distance is five feet and the pitches become greater in the lower part. The river, along these rapids, is between 40 and 60 feet wide; the banks are low and marshy in the upper part but somewhat higher (five to ten feet) in the lower section.

Situated immediately below Whitefish river, and extending over a distance of two miles, is another series of five rapids, with a total descent of five feet.

The discharge of Methy river, taken in September, 1912, was found to be 95 cubic feet per second, at a point one-quarter mile above the mouth of Whitefish river. The river was 53 feet wide at this point, the maximum depth 5·4 feet, and the greatest mean velocity in any one section 0·57 of a foot per second.

CHAPTER XVII

Yukon River and Tributaries

The Yukon is navigable for steamers from its mouth, on Bering sea, up the Lewes branch as far as Whitehorse rapid.

This great stream has an average width in Canada of over 400 yards and, flowing around numerous low, wooded islands and shifting bars, has a steady current of about five miles per hour. Its valley is comparatively narrow, with few flats, while the river, sweeping from bank to bank in easy curves, washes alternately the bases of the hills on either side.

Although the Yukon river proper is free from rapids, many of these exist on several of its tributaries.

Various estimates have been made of the discharge of the Yukon by both United States and Canadian engineers, but, until 1911, it had not been found practicable to establish a regular gauging station on this river. In May, 1911, a station was established by the U. S. Geological Survey at Eagle, Alaska. As this town is very near the international boundary, the results obtained are of equal interest to Canada.

The following table shows the mean monthly discharges for the years 1911-1913 at Eagle, Alaska:

Month	Mean discharge in second-feet			Second-feet per square mile		
	1911	1912	1913	1911	1912	1913
January	21,000	21,000	21,000	0.172	0.172	0.172
February ...	15,000	15,000	15,000	.123	.123	.123
March	11,000	11,000	11,000	.090	.090	.090
April	12,000	12,000	12,000	.098	.098	.098
May	156,000	125,000	117,000	1.28	1.02	.959
June	184,000	160,000	199,000	1.51	1.32	1.63
July	178,000	147,000	164,000	1.46	1.20	1.34
August	139,000	127,000	133,000	1.14	1.04	1.09
September .	106,000	73,600	90,000	.869	.603	.738
October ...	60,000	51,000	55,000	.492	.418	.451
November .	37,000	37,000	37,000	.303	.303	.303
December ..	28,000	28,000	28,000	.230	.230	.230

A maximum discharge was observed on May 22, 1911, when the discharge was 253,000 second-feet.

In the summer of 1887, Dr. G. M. Dawson found the flow at fort Selkirk to be 66,955 cubic feet per second. Water-marks indicated

that in the preceding spring the flood discharge had been at least 167,400 c. f. s. The engineers of the Dominion Water Power branch are now making a reconnaissance examination of the water-powers of the Yukon territory preliminary to a thorough investigation of its water resources.

Porcupine River

The Porcupine heads near the Yukon river, approximately in latitude 65° 30′ N., and after describing a great semi-circular curve to the northeast, falls into the same river a hundred and fifty miles farther down. At its most easterly point it approaches within eighty miles of the Mackenzie, but is separated from it by the main range of the Rocky Mountains. Its total length approximates 500 miles.

From its headwaters in three small lakes the Porcupine flows northward as a fair sized stream in a valley one mile wide, the bottom of which is well timbered. The descent in the river in its extreme upper portion is very steep, 200 feet per mile being estimated in some places. The river has numerous tributaries and rapidly increases in size. Immediately above the Fishing branch, the descent is fairly steep and estimated at 400 feet in eight miles. The river leaves the mountains opposite mount Dewdney, twenty miles below the Fishing branch, the descent being 300 feet in this distance. There are no dangerous rapids on the river which, everywhere, flows with a swift current over a bed of lime gravel. Below its exit from the mountains it winds through an undulating and wooded country, the banks being nowhere more than 100 feet high and generally of clay with black shale exposures. Above lat. 66° 30′ the river is too swift for steamboat navigation but below this point, no difficulty would be found for moderate sized craft as the current becomes very slow and the descent in the river almost inappreciable.

From Bell river to Driftwood river, a distance of over forty miles by the course of the river, the Porcupine has a general north-westerly trend, but makes a couple of minor bends to the north-east. Its width varies from one hundred and fifty to two hundred yards, and its current barely averages two miles an hour. The valley is generally rather wide and shallow, but at one point about ten miles below Bell river, becomes somewhat contracted, and for some miles has the appearance of a wide cañon. The banks here are high and steep, and are formed of broken fragments of hard quartzite. Below the contraction it resumes its usual character.

Below Driftwood river the Porcupine makes a sudden bend of several miles to the north, and then turns west to the head of the Ramparts. The distance between these two points, measured along

the tortuous course of the river, exceeds seventy-five miles. The river in this reach has a width of from 200 to 300 yards. No rapids occur, and the current does not average over two miles an hour.

The Porcupine while passing through the Ramparts contracts considerably, and in places does not exceed seventy-five yards in width. Its current is more rapid than in the upper part, and was estimated to run at the rate of from three to four miles and a half an hour. Short riffles, with a much greater velocity than this occur occasionally, but no rapids or other obstructions are met with, which would prevent the navigation of the stream by small steamers. In the upper part of the Ramparts the banks rise steeply from the water's edge on both sides to heights of from three to five hundred feet.

Klondike District

The Klondike gold fields have two important water-power developments which have been in use for some time. From the description of these, it may be judged that good water-power sites are not lacking in this district, but, unfortunately, little information is available except regarding those in actual use.

This district is situated on the east side of the Yukon river, and comprises approximately 800 square miles in the vicinity of the mouth of the Klondike river. At present most of the gold mining is done by companies which have spent millions of dollars in equipment and installation, and are obtaining the gold mainly by dredging and hydraulicking, the dredges usually being operated by electrical energy generated by water-power.

Yukon Gold Co.'s Development

The Yukon Gold Company's hydro-electric plant is on the Little Twelve-mile river, one-half mile from its junction with the Big Twelve-mile or Chandindu river. Water is available from two sources, the Little Twelve-mile and Tombstone rivers. It is diverted from these rivers at points six miles and ten miles, respectively, from the power plant and carried to the plant by means of flumes; a static head of 710 feet is obtained, which is reduced to 680 feet under full load conditions. The equipment consists of three units of 54-in. single runner Pelton wheels, each direct-connected to a 625-k.w. revolving field generator running at 450 r.p.m. The load is very fluctuating, varying from 200 to 2,000 k.w. The electrical energy is generated at 3-phase, 60 cycles, 2,200 volts, and the voltage is stepped up to 34,000 volts; at this voltage it is transmitted to three sub-stations, two on Bonanza creek and one on Hunker creek. At the sub-stations it is stepped down to 4,400 volts and delivered to the eight dredges and various other mining machinery. At the point of consumption it is further reduced to 440 volts to operate the motors.

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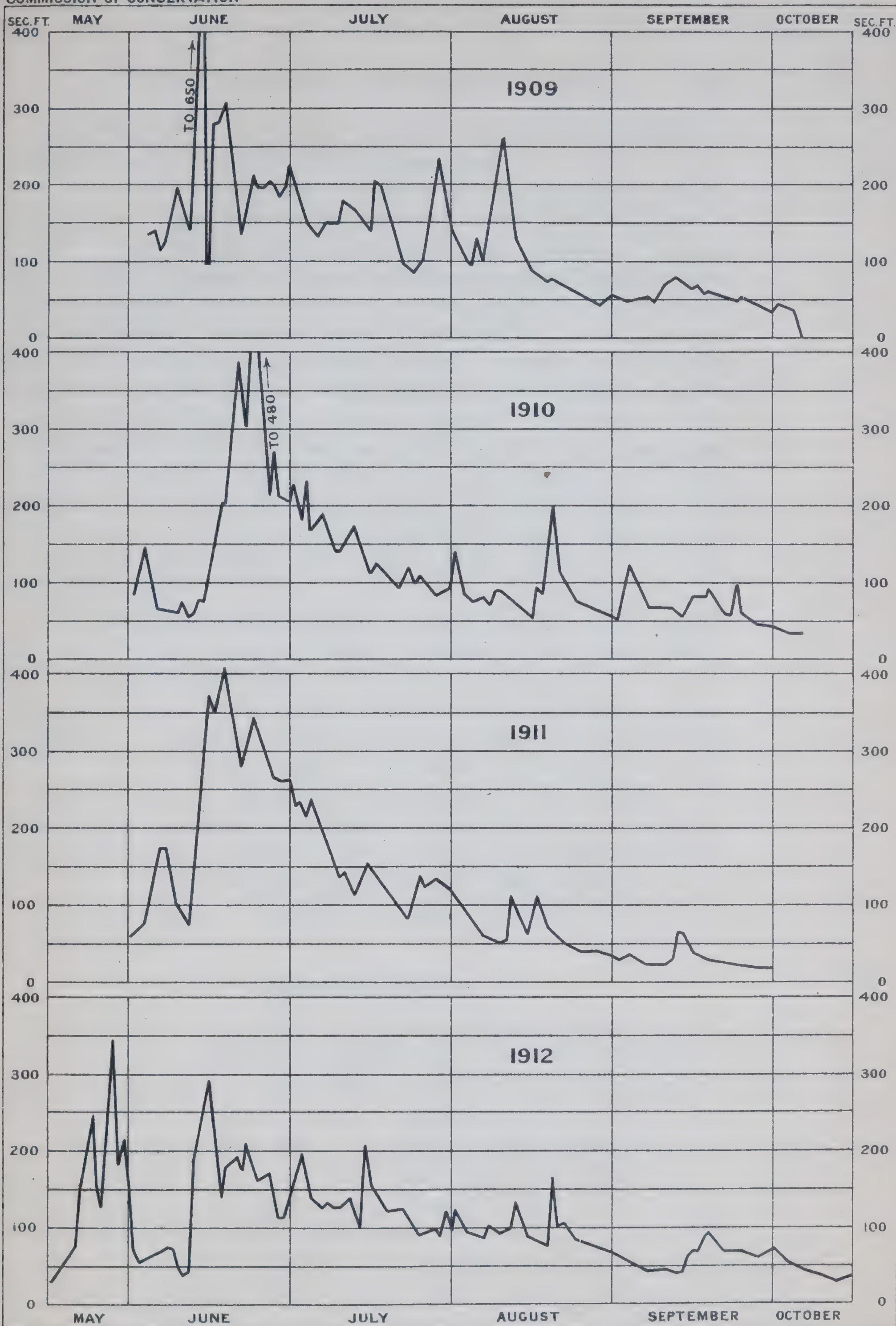

LITTLE TWELVE-MILE RIVER, YUKON
HYDROGRAPHS FOR SEASONS 1909-12

An additional line, 27 miles in length, is now under construction, to supply another sub-station at Gold-run creek.

Artificial Waterway

A feature of greater interest connected with the operation of this company is the giant ditch used to convey water for hydraulicking purposes. The main ditch receives its supply of water from the system supplying the power station on Little Twelve-mile creek. It comprises 64 miles of main line, composed of 15 miles of flume, 37 miles of ditch and 12 miles of pipe line, crossing five depressions. It has a capacity of 1,250 cubic feet per second and delivers water under a head of 500 feet at the Lower Bonanza hills. The Bonanza extension is 6 miles in length, has a capacity of 750 cubic feet per second, and crosses three depressions. The total length of the ditch system and extensions is 75 miles. A reservoir, known as the Bonanza dam, is used in connection with this system. As its name implies, it is on Bonanza creek, and has a capacity of 43,600,000 cubic feet, covering an area of approximately 40 acres.

It is stated that sufficient water for operating is usually available from May 15 to October 10; water not used at the power plant is diverted into the main ditch.

North Fork of Klondike River

The Canadian Klondike Power Company's power-house is near the junction of the North fork and Klondike river. The water is brought from the North fork, over a distance of six miles, through penstocks. The head obtained is 228 feet. There are two units, each consisting of a 5,000-h.p. Morris turbine, direct-connected to a 3,000-k.w. generator. The electrical energy is generated at 3-phase, 60 cycles, and is transmitted 25 miles to dredges operating in the Klondike, Bonanza and Hunker valleys.

Stewart River

The Stewart is one of the main tributaries of the Yukon. It rises in the unexplored Pacific-Arctic watershed ranges lying between the heads of the Peel and Pelly rivers, and flows in a general westerly direction toward the Yukon valley. From Fraser falls to its mouth, a distance of nearly 200 miles, it is a large stream, seldom less than 150 yards in width and often more than double this breadth. It is navigable by ordinary shallow-draught steamers to Fraser falls. From the Mayo river to its mouth, the current flows from three to five miles an hour with occasional accelerations on the bars. Above Mayo river, the current decreases to two to three miles an hour and bars are almost entirely absent. At the Fraser falls, the Stewart flows for a

third of a mile with great velocity through a narrow cañon bounded by vertical walls of hard quartzose schist. The word "falls" is a misnomer, as the grade in the cañon is fairly uniform and the total descent is estimated to be only 30 feet. Above the falls the river is interrupted by occasional short riffles for several miles, but, farther up, its course is reported to be clear to the main forks, a distance of about 60 miles, and up the North branch for a considerable stretch beyond. The East branch is reported to be a rapid stream constantly interrupted by rapids and cañons. The principal tributaries of the Stewart below Fraser falls are the McQuesten and Mayo rivers, both fair sized streams, and Clear creek from the north, and Crooked river, Lake creek and Scroggie creek from the south.

Pelly River

The total length of the Pelly, following the course of the river from the Pelly lakes to the confluence with the Lewes, is 350 miles. A measurement in the summer of 1887 by Dr. G. M. Dawson indicated that the discharge at "Pelly Banks" was 4,898 cubic feet per second. The elevation at Campbell portage, 30 miles below the lakes, is approximately 2,965 feet, while that at the confluence is 1,555 feet, giving a total descent of 1,410 feet or 4.4 feet per mile. A considerable portion of the descent, however, occurs in numerous small rapids. Many islands are encountered along the course of the river, which follows two general directions, the first bearing N. 55° W., the second, N. 87° W. These are parallel to the principal orographic features, respectively, of the upper and lower parts of the country traversed, and indicate the main slopes of the region.

Just below the mouth of Hoole river, a rapid 600 feet long has a total fall estimated at ten feet. From this rapid to Hoole cañon, the stream is swift and contains several small rapids.

The banks and beaches of the Pelly, above Hoole river, are generally silty or muddy, although the strength of the current is sufficient to produce well-washed gravel-bars in midstream. Below Hoole river, the banks and beaches are as a rule gravelly, due to the swifter flow.

At Hoole cañon, the river bends to the north-eastward and is confined between rocky banks and cliffs, about 100 feet in height. The descent in the cañon is 20 feet in a distance of three-quarters of a mile, measured along the river, or one-half mile by portage.

The Pelly, between the cañon and Ross river, is swift and contains numerous small rapids. For slightly more than half the distance between the Ross and Glenlyon, the river continues to flow rapidly amid many islands and gravel-bars; the remaining portion is comparatively tranquil, with the exception of the two rapids in the im-

mediate vicinity of the Glenlyon. The first occurs at an S-shaped bend, two miles east of the Glenlyon, while the second is immediately below the mouth of that stream. The upper rapid is wide and rather shallow, with rocky impediments. It is easily run with a canoe, but passage by steamers, except those of light draught, is dangerous at low stages of the river. The current in the second rapid strikes directly on the face of a rocky bank on the right of the river, forming a heavy, confused wash, but is otherwise unimpeded and deep.

For a distance of 20 miles below the Glenlyon river, the Pelly is unusually free from abrupt bends, and islands are few. It is bordered on the south by the Glenlyon mountains, the summits of which exceed 5,000 feet in height.

Twenty miles from the Glenlyon, the river turns abruptly northward, following an S-shaped bend, called the Detour, and cutting completely through the ridge which has previously bounded it on that side. As far as the lower end of the Detour, the current is rather swift, with a number of small rapids, although none is of such a character as to impede navigation.

The Granite cañon, below the mouth of the Macmillan, is nearly four miles in length, with steep, rocky, scarped banks and cliffs, from 200 to 250 feet in height. In the cañon are several minor rapids, but the water is deep, and, except for isolated rocks, navigation would be quite safe for steamers, even at a low stage of water.

Macmillan River

The Macmillan river has a total length of about 285 miles. In the summer of 1887, Dr. Geo. M. Dawson determined the discharge at its mouth, 9,796 c.f.s. It divides at 150 miles above its mouth into two nearly equal branches, known as the North and South forks. The North fork carries the most water, and has a length of about 135 miles. The South fork is probably of nearly equal length.

The main river, in the first fifty miles, varies in width from 300 to 500 feet, the current seldom exceeding three miles an hour.

About fifty miles above the mouth, there is a stretch of rapid water five or six miles in length, above which the current is again generally slack for a further distance of fifty miles, although a few riffles occur. In the upper fifty miles, the current becomes much swifter, flowing at a rate of from three to five miles an hour. The swiftest stretches occur at places where the stream has recently broken through the necks of ox-bow bends, and so shortened its course. The greater portion of the river is easily navigable, except at low water, by small steamers.

The grade of the Macmillan is estimated at from one to two feet

per mile in the lower portion of the river and from two to four feet in the upper portion. The average grade throughout probably amounts to about three feet to the mile and the total fall from the "forks" to the Pelly is estimated at 450 feet.

The North and South forks are nearly equal in size, but the former carries a much larger volume of water. The North fork is an exceedingly rapid stream and bears more resemblance to a mountain torrent than to an ordinary river. Between the forks and Cache creek, a distance of about 70 miles following the windings, the river falls about 12 feet to the mile. The current is uniformly swift throughout, running at the rate of from five to eight miles an hour. The channel in places is filled with boulders, and strong riffles are frequent, especially for some miles above and below the mouth of Husky Dog creek, but no strong rapids necessitating portages occur below Cache creek. Two and a half miles above this is the Big Alec rapid, a rough bedrock rapid a quarter of a mile in length.

The South fork at its entrance to the main river is 250 feet wide; the current is slack for several miles above its mouth. For the first twenty-five miles, following the windings of the stream, the average grade is about three feet to the mile; from this to the cañon the grade is probably five feet. The speed of the current varies from two to five miles an hour. The cañon is 58 miles from the Forks, and about half a mile in length, the river breaking into three rapids on its course through it. Beyond the cañon the valley widens out, the grade increases and the river runs swiftly around sharp bends and resembles the North fork in character during the remainder of its course.

Ross River

The Ross is one of the principal tributaries of Pelly river. Rising in the western slope of the divide between the Mackenzie and Yukon basins, it flows in a general southwesterly direction. Discharge, at its confluence with the Pelly, in the summer of 1887, was 4,900 feet per second.

For six miles above its mouth it is broken by swift water, the total descent in this distance being approximately 60 feet. Above this point, it flows for about seventy-five miles with moderate current, and several shallow riffles.

At False cañon, some twenty miles from the mouth, the descent is inappreciable although the current is quite swift; the banks immediately above the cañon being low, it would be difficult to develop power. From this point to Prevost cañon, approximately 70 miles above, the descent in the river averages 2.5 feet per mile. Prevost

cañon offers better conditions for power development; the descent in it is 20 feet in one mile and banks are of steep rock. There are two other rapids a short distance below and one eight miles above the cañon over which boats can only pass after being unloaded. The current in this portion of the river is everywhere very swift. Sheldon lake, twenty miles above Prevost cañon, is the limit of boat navigation in low water, but in high stages, Wilson lake, forty-five miles beyond, might be reached, the latter being only thirty miles from the divide. The cañon, 15 miles above Sheldon lake, offers no power possibilities as there is only swift water with no appreciable descent. Above Wilson lake to its source the stream assumes a very steep descent but the flow is so restricted as to exclude power development. As an example of the grade in its upper portion it is estimated that the stream descends some 600 feet in the first ten miles from the divide, and the descent in the next 30 miles below is approximately 825 feet.

Lewes River

The headwaters of the Lewes include several lakes, notably, Atlin lake 2,200 feet above sea and Tagish and Bennett lakes, 2,148. It flows in a north-westerly direction, joining the Pelly river at Selkirk to form the Yukon river. Immediately below the headwaters of the Lewes is lake Marsh, connected with Tagish lake by a wide, tranquil reach of river, five miles in length.

Lake Marsh is 20 miles in length, with an average and very uniform width of about two miles. The valley, of which this lake forms the centre, is very wide; the country in the immediate vicinity of the lake is low, consisting of terrace-flats, or low, rounded or wooded hills and ridges.

In the summer of 1887, the discharge of the Lewes above the mouth of the Teslin was 18,664 c.f.s.; below the Teslin, it was 30,100.

Whitehorse Rapid and Miles Cañon

About 30 miles below lake Marsh, the Whitehorse rapid and Miles cañon together form the most formidable obstacle to the utilization of the Lewes as a route into the interior, constituting a series of rapids two and three-quarter miles in length.

The cañon is cut through horizontal, or nearly horizontal, basalt, and is not more than 100 feet in width; vertical cliffs, averaging 50 feet, and never exceeding 100 feet in height, rise at the sides. It opens out into a basin in the middle but, elsewhere, the river is inaccessible from the banks. Terraced hills rise above the basalt walls on each side of the valley, being particularly abrupt on the west bank. Although the river flows through the cañon with great velocity, it is unimpeded in its course, and is, therefore, not very dangerous to run with a good boat.

Between the Whitehorse and the foot of the cañon, the river is very swift. The descent in the cañon and Whitehorse rapid, covering the whole stretch of rapid water, is 49 feet. Additional fall, if necessary, can easily be obtained by damming the river at the head of the cañon. Its width here is about 90 feet, and it is enclosed between nearly vertical basalt walls.

Lake Laberge, the lowest lake-expansion on this river, is 27 miles below Whitehorse; it is 31 miles long and from one and a half to five miles wide. It lies nearly north-and-south, but is somewhat irregular in outline and does not present the parallel-sided form and uniform width characteristic of the mountain lakes.

Five-finger rapid, situated 55 miles above the mouth of the Lewes, is caused by the presence of several rugged, rocky islands which obstruct the river. The rapid is only a few yards in length, where the water flows swiftly between the islands. The channels are deep and unobstructed.

Below the main rapid, is a second minor rapid, which appears to be somewhat stony.

From its mouth to Five-finger rapid, the course of the Lewes is nearly straight, flowing north-westerly. In this portion of the river the current is swift throughout.

Teslin River

The Teslin river is the largest tributary of the Lewes. It is a large stream, averaging about 125 yards in width when confined, but expanding around islands. It has a total length of nearly 100 miles. The current is moderately swift for the first 70 miles above the mouth, varying from three to five miles per hour, with occasional accelerations where bars cross the stream. Thirty miles below Teslin lake, the grade lessens and the current decreases to less than two miles per hour. No rapids occur on the Teslin, but bars are frequent, and, on some of these, the water is so shallow in autumn as to interfere with navigation.

Discharge at its mouth, in the summer of 1887, 11,436 cubic feet per second.

Atlin River

Tagish lake receives the waters of Atlin lake through one of its southern branches in British Columbia called Taku arm. Atlin river, the short stream connecting Atlin lake with the Taku arm, is reported to possess water-power possibilities. It is three miles in length, following its windings, with a descent of 38 feet, but the short railway between the two lakes leading over a low ridge is only two miles long.

CHAPTER XVIII

Coppermine, Hood, Dubawnt, Ferguson and Kazan Rivers

The Coppermine river rises in approximate lat. 66°, long. 110°, flows south to lac de Gras, thence west and northwest to Coronation gulf; it is between 400 and 500 miles in length. The stream is swift but shallow and is broken by numerous rapids; most of these, however, can be descended in canoes under the guidance of expert canoemen. The river ice breaks up about the first of June and forms again about the first of October.

From Point lake the river falls into Red Rock lake, over a rapid 100 yards wide, and flows thence into a smaller lake. Below this lake is a succession of rapids, extending for three or four miles, and bounded by rocky banks. Beyond the rapids, the stream expands to about 300 yards, flowing with a slower current. Rapids and calm water then alternate as far as the mouth of Fairy river, where the rapids end. Approximately 90 miles farther downstream, at the bend where the river resumes its northerly course, it narrows and forms a series of rapids. This section of the river flows between high ranges of mountains and the banks are of mud and clay. At the Rocky Defile rapid, near the mouth of the Kendall river, the Coppermine rushes turbulently for three-quarters of a mile in a deep, narrow and crooked channel; the banks, which resemble stone walls, rise to a height of 80 feet. For a short stretch the river is shoaly, below which it again becomes swift, flowing between banks of sand and gravel over numerous, shallow rapids. Above and below Escape rapid, it flows between high, sandstone banks and is full of shoals and swift rapids. Bloody fall occurs about ten miles from the mouth of the river; it is a shelving cascade, about 300 yards long, having a descent of 12 feet. Both banks consist of high walls of red sandstone,

Hood River

Hood river flows into Arctic sound, one of the inlets south of Coronation gulf. It is from 100 to 200 yards wide near its mouth, with high, steep, clay banks and many sandy shoals. Ten miles above its mouth is a cascade from 18 to 20 feet high, caused by a ridge of rock.

For a distance of seven or eight miles above this cascade, the river is full of shoals and rapids, until the foot of Wilberforce fall is reached. This fall occurs in a narrow chasm with almost perpendicular walls rising to a height of 200 feet. The river precipitates itself over the rock, forming two very picturesque falls in close proximity. The upper fall is approximately 60 feet high and the lower one over 100 feet, while the total descent at this point probably exceeds 250 feet.

Dubawnt River

The Dubawnt river rises in Wholdaia lake, at an altitude of 1,290 feet above the sea. It flows north-north-eastward for 285 miles, following its curves, to Dubawnt lake, descending in this distance approximately 790 feet. For 175 miles of the course, it comprises the quiet water of larger or smaller lakes; the 110 miles of running water thus has an average descent of slightly more than seven feet per mile. The channel is shallow, and both banks and bed are mainly composed of boulders. Its total length, from the head of Wholdaia lake to the head of Chesterfield inlet, is 750 miles.

From Wholdaia lake the river flows in two channels, and, after a course of two miles and a half, opens into a small, irregular lake, with low, sandy or stony shores; the underlying gneiss shows at but few places. From the north-western side of the small lake, the river flows as a rapid stream, 250 yards wide, with an even bed of boulders, but so shallow that in summer there is insufficient water for canoes.

Timber and Vegetation

Groves of stunted black spruce are found here and there; the trees are from six to fifteen feet high and usually much expanded at the base. Larches, scattered among the spruce, are much the tallest and largest trees in the groves. Their trunks, from eight to ten inches in diameter, are spirally twisted in the grain.

Below the rapid portion above referred to is another small lake, with low, treeless, grassy shores and occasional sandy beaches. Beyond this again is a long, tortuous rapid, with a descent of about 12 feet, where the stream is crossed by a ridge of rock. At the foot of the rapid is a short stretch of quiet water. For five miles below this quiet water the river is very swift. The banks are low and grassy, and the country is flat and sandy or boggy; hills are rarely seen, while the underlying rock is nowhere exposed.

The river then expands into an oblong lake, three miles in length; below the lake a long rapid, terminating in a swift chute over a rocky barrier, has a total descent of about 20 feet.

Ptarmigan rapid is a long, swift chute, at the outlet of Hinde lake, passable by skilful canoemen.

Ten miles downstream the river flows in a heavy rapid, between morainic hills; the sides of the channel are formed of walls of angular fragments of rock piled up and shoved back by the ice of the spring.

Below Boyd Lake

At the foot of the rapid, the river expands into Boyd lake, 21 miles long. For seven miles below Boyd lake, the stream skirts hills of boulders, with a rapid at every bend, and here, in the bottom of the valley, occurs the first exposure of rock seen for many miles. For three miles and a half farther down, the stream flows through a low-lying country, diversified by small sandhills, boulders and broken rock. For the next five miles it flows in devious channels, usually with a swift current, at one place breaking into a swift rapid. The banks are gently rounded, stony slopes, green in parts with grass and moss.

At the outlet of Barlow lake a heavy rapid descends about 12 feet; the banks consist of large boulders of red gneiss.

A heavy rapid three miles long, with a descent of about 55 feet, is situated below Carey lake; the upper portion of the rapid is divided by a low, stony island. Below the rapid the river continues to flow in a north-easterly direction for several miles; there are stony, grassy slopes to the southeast and a glaciated rocky shore to the northwest.

The river flowing from Markham lake is wide, and in places rather shallow, with a swift current. After a course of a mile and a half, it empties into the southeast side of Nicholson lake.

From the north end of Nicholson lake, it flows northward for two miles and a half down a heavy rapid, with a descent of about 40 feet; toward the foot of the rapid the bank is formed by abrupt cliffs of reddish, sandy till, filled with boulders, and steep walls of gneiss. Near the foot of the rapid the stream turns eastward, and for about six miles flows in the bottom of a valley from 150 to 200 feet deep. The banks are composed of gneiss, while several narrow ridges of sand and boulders extend through the valley parallel to the sides.

Dubawnt Lake

The river then becomes more diffuse and irregular; after flowing for several miles it divides into a number of channels, as it enters an oblong lake, four and a half miles long. Between this lake and Dubawnt lake there are several short rapids over low ridges of gneiss. Dubawnt lake is a large body of clear, cold water, at an approximate altitude of 500 feet above sea-level. In August, 1893, it was covered with ice except near the shores.

The outlet of Dubawnt lake is about 200 yards wide. It descends two slight rapids, and then, with a current of four miles per hour, flows through a wide and almost level plain, underlain by reddish till containing small pebbles and boulders. The channel rapidly deepens, with steep, green banks, and the stream rushes over long, swift rapids which test the dexterity of expert canoemen.

Seven miles below Dubawnt lake, the river suddenly contracts, and for two miles dashes, as a foaming torrent, down a narrow gorge about 25 yards wide, descending 100 feet in the distance. The northwest bank is an almost continous wall of rock; the southeast bank is a steep, sandy slope, with numerous rocky points projecting into the gorge. At the foot of this heavy rapid, the river empties into Grant lake, which is seven miles long. On August 19, 1893, this lake was partly covered by an unbroken field of ice.

For a distance of eight miles below Grant lake, the river is from 200 to 400 yards wide, with a current of from three to six miles per hour. The low banks are composed, at first, of stratified gravel, but afterwards of rough masses of gneiss. At the end of this distance is a heavy rapid, full of large boulders, caused by the stream flowing over a band of rock. The river then expands into three small lakes, below which, for three miles and a half, the current is very swift; at one point there is a fall of ten feet, over a ledge. A portage 250 yards in length passes this fall on the south side.

Wharton lake, situated one mile and a quarter below the last-mentioned rapid, is 21 miles long and its greatest width is about seven miles. Below Wharton lake the river flows at first eastward, and then southward for four miles to a small lake. In this distance occur two rapids, with descents of 15 and 6 feet respectively. Five miles below the small lake is a rapid with a descent of 20 feet, passed by a portage 400 yards long. At the foot of the portage the river turns at right angles and flows northward through low country for seven miles as a wide, shallow, rapid stream.

Lady Marjorie Lake

From Lady Marjorie lake, the stream flows northwestward for two miles to a swift rapid, falling over a ridge of granite, with a total descent of about 20 feet. Fifteen miles below Lady Marjorie lake, the stream narrows suddenly to a swift rapid, between walls of rock; below this, for several miles, it flows in a well-defined channel 200 yards wide, with steep banks of boulders and till, gradually increasing from 50 to 100 feet in height. Twenty-six miles below Lady Marjorie lake, a narrow dyke of green diabase crosses the river, forming a heavy rapid, called Loudon rapid; for the next five miles, the stream continues to flow

north-westerly, with a current of four miles per hour. The banks, from 50 to 100 feet in height, are often scarped. The river has all of the characteristics of a prairie stream; rolling prairie extends on both sides, and steep banks of till descend to the water.

Aberdeen lake is 45 miles in length and about 16 miles wide in its broadest part, with an area of from 200 to 300 square miles. Schultz lake, which is 24 miles long, receives the Dubawnt river at its western end. From this lake the water flows northward for one mile and a half, descending a swift but deep rapid with a fall of five feet. It then enters a gradually deepening valley, and flows at the rate of six or seven miles per hour, between banks of stony till, thence south to Baker lake, which is approximately 45 miles long, and into Chesterfield inlet.

Thelon River

The Thelon is reported to rise in lakes northeast of lake Athabaska, but its upper portion still remains unexplored. It flows north for the greatest portion of its course, turning sharply to the east in its lower course before entering Beverly lake. Above Eyeberry lake the river flows through prairie stretches, interspersed with spruce and tamarack groves. In this as well as in the portion below the lake a few rapids are encountered. Below the mouth of the Hanbury river it flows for 224 miles to its mouth, the average width being 250 yards, the depth, 6 feet, and the current running three miles per hour. Over this entire portion, although several points with swift current are met, none of these can be called rapids as they may easily be passed in canoes.

Ferguson River

Ferguson river rises in Ferguson lake, in latitude 63°, about 20 miles east of the north end of Yathkyed lake; it flows east-south-eastward, parallel to Chesterfield inlet and at right angles to the course of Kazan river, directly into the west side of Hudson bay. Its total descent from source to mouth is about 400 feet, and its total length approximately 180 miles. In its lower portion it flows through a country of bare, rocky hills, but the lakes in its upper section lie in the midst of undulating, grassy prairie.

Below Kaminuriak lake the stream flows very rapidly for a third of a mile, with a descent of about four feet; then it opens into a small lake, below which it flows in two channels, enclosing a large, flat, grassy island. The eastern channel is wide, and its current sluggish as far as the head of a heavy, crooked rapid; there it is obstructed by a trap dyke, over which the water falls in an irregular

cascade, with a descent of 15 feet. At the foot of this cascade the western channel again joins the eastern.

Farther downstream two small lakes are met, and the river flows rapidly from the end of the second lake north-eastward for two miles to a rocky gorge. It then turns south-eastward for two miles and a half among bold, rocky hills; reaching a heavy rapid, the water rushes through a narrow, obstructed channel between steep walls of diorite. Below this rapid, it flows eastward for two miles, in a straight channel, with steep, rocky banks, and then traverses a small lake, whose outlet descends a rocky rapid for three-quarters of a mile. At the foot of the rapid, a portage, 800 yards in length, follows the east bank past another rapid which flows over boulders and jagged points of rock. Beyond the portage the river is swift but sufficiently deep for canoes; it flows between banks of rock, to a small fall which can be run with half-loaded canoes. Below this *demicharge* the river opens into Quartzite lake.

Ten miles below Quartzite lake, the river breaks over a ledge of rock passed by a portage of 400 yards. Beyond this it traverses a small lake, and flows rapidly through till-covered country, studded with low hills of boulders, to a swift chute, rushing through a narrow gap in a high ridge. The stream is then broken by two shallow rapids, and enters the northwest end of a narrow lake about six miles and a half long. This is the lowest lake on Ferguson river; from its south-eastern end, the river continues its very rapid course south-eastward for eight miles. Turning abruptly eastward, it flows with an easy current in a wide channel, with ridges of boulders roughly parallel to it on the south and a low escarpment of till about a mile distant on the north. For two miles farther eastward, it continues with varying current to a strong, crooked rapid, one-third of a mile long, over a bed of rock. Below this rapid, which can be traversed by canoes without much difficulty, is one-half mile of smooth water, to the head of another short rapid with a fall of ten feet.

For three-quarters of a mile below this rapid, the river has a moderate current, after which it contracts and flows swiftly between steep walls of granite and trap. Immediately below this short gorge, it spreads over a wide bed of rounded pebbles, and, flowing swiftly for two miles and a quarter, passes through a rocky gap, and empties into Hudson bay at the head of Neville bay.

Kazan River

The Kazan river rises in Kasba lake, which lies 50 miles east of Wholdaia lake and at an elevation of 1,270 feet. From this lake, the river flows for 220 miles north-north-eastward, parallel to the course of the Dubawnt river, to Angikuni lake. Throughout this distance the sloping shores are composed chiefly of boulders or boulder-strewn till. From Angikuni lake, the river turns sharply eastward for 90 miles, thence northward for 35 miles to Yathkyed lake. Below Yathkyed lake it has a length of probably 90 miles, to its mouth on the south side of Baker lake, giving it a total length of 490 miles.

From Kasba lake the river flows with a slight current, over a bed of boulders to a lakelet. Below this it enters a well-defined channel, which varies in width from 100 to 300 yards, and rushes down a series of swift, tortuous rapids. These extend for a mile and three-quarters to the head of a cascade, with a descent of 15 feet. Thence, the river, traversing two small lakes, continues swift, in a shallow but well-defined, winding channel with wooded banks of sand or boulders, until the foot of the slope is reached at Ennadai lake. The descent from Kasba lake, a distance of 16 miles in a straight line, is approximately 170 feet.

For two miles below Ennadai lake, the Kazan forms a heavy rapid, flowing over a bed of boulders. From the bend at the foot of this rapid, it flows swiftly eastward in a shallow channel over a bed of pebbles and boulders, descending about 200 feet in a distance of 17 miles, measured in a straight line.

A short distance below Sandy Hill lake, the river bends sharply to the north and continues to flow very rapidly for two miles; then it gradually widens and the current slackens, until, at several sandy ridges, it empties into the south end of a narrow lake, bordered by stony ridges. The water discharges on the east side of this lake in a swift rapid over a rocky cascade.

From the outlet of Angikuni lake, the river flows eastward for 44 miles, with a constantly varying current; at times it rushes headlong down a narrow channel, and, again, spreads out over a wide bed of boulders, packed by the ice into as even a pavement as the size and shape of the boulders permit. In two places the river expands into small lakes. At a point 30 miles below Angikuni lake, it falls 20 feet over a ridge of gneiss, beyond which it flows with a rapid current to a second fall. Below this is a heavy cascade, through a narrow, rocky gap, where the river enters a gorge; the depth of the gorge, 60 feet, represents the total descent from the head of the upper fall, a distance of a mile and one-half.

For 17 miles the river is an almost continuous, heavy rapid, at the end of which is a portage, one-half mile long. This portage is on the south bank and passes rough water, where the river drops in a series of cascades over rocky ledges, descending about 20 feet. Below this rocky portage, the stream flows rapidly eastward for five miles; it then bends to the north, and continues for ten miles to flow over a bed and between banks of boulders, with a strong current. At the end of this ten-mile reach, it expands into a small lake two miles long; the outlet of the lake is a heavy rapid, 140 yards long, with a fall of ten feet over a ridge of gneiss.

For five miles and a half, the stream continues with a moderate current in a channel which bends toward the west, until it rushes with a very strong current between rocky islands, and thence, in a low fall, over a rocky ledge. Below the islands, it widens and becomes less rapid, flowing between sandy banks. Ten miles beyond is a place called by the Eskimos "Palelluaw," where the river is deep and narrow.

Below Palelluaw the river remains deep, with a slackening current, and the banks of sandy slopes are replaced by rugged walls of angular boulders.

Kazan river gradually widens to a bell-shaped mouth, with no trace of a delta deposit, where it enters Yathkyed lake. From this lake it flows north into Baker lake, but has been explored only for a distance of twenty-five miles, to a point where the portage to the headwaters of the Ferguson river is made. In these twenty-five miles two rapids and several small lakes occur, and a high fall is reported farther down at a short distance above the mouth of the river.

Appendix I

TABLE OF WATER-POWERS ON SASKATCHEWAN RIVER AND TRIBUTARIES AND STREAMS FLOWING INTO LAKE WINNIPEG

Reference numbers preceding the names of power sites correspond to numbers on Water-power map in pocket.

Power site	Possible available head in feet	Horse-power		Remarks
		Theoretical minimum available	Used at present	
WINNIPEG RIVER:				
1. Pine	37	50,400 *a* 84,000 *b*		
2. Du Bonnet	56	76,200 *a* 127,000 *b*		A preliminary head of 46 feet could be developed at first.
3. McArthur	18	24,500 *a* 40,900 *b*		
4. Upper Seven Sisters	29	13,200 *a* 39,500 *b*		Flow through Pinawa channel has been deducted in calculating h.p. available.
4. Lower Seven Sisters	37	16,800 *a* 50,500 *b*		
5. Pinawa channel	39	35,500	28,200	*Winnipeg Electric Ry. plant.
5. Upper Pinawa	18	16,400		
6. Slave fall	26	35,500 *a* 59,100 *b*		
7. Point du Bois	45	61,400 *a* 102,000 *b*	47,000	†Winnipeg Municipal electric plant.
WHITEMOUTH RIVER:				
8. Whitemouth fall	20	102 *i*‡		At mouth of river.
9. Below town of Whitemouth	20	102 *i*		Three miles below town.
ROSEAU RIVER:				
10. Near Dominion City	15	68 *g*		Local report; not surveyed.
RED RIVER:				
11. Lockport, Gov. dam	15	3,400 *g*		
SOURIS RIVER:				
12. Above Souris	25			One mile above town.
ASSINIBOINE RIVER:				
13. Currie Landing	18	92 *e* 242 *g*		Seven miles east of Brandon.
14. Millwood	18	123 *e* 370 *g*		Abandoned mill site.

(*a*) Shows possible h.p. for the minimum natural flow of the river, assumed as 12,000 second-feet.

(*b*) Shows possible h.p. for the minimum regulated flow of the river, assumed as 20,000 second-feet.

*34,000 h.p. installed; 28,200 h.p. now (May, 1916) in use.

†47,000 h.p. installed; 25,000 h.p. now (May, 1916) in use.

‡For footnotes *c* to *j*; see end of Appendix I, p. 280.

Power site	Possible available head in feet	Horse-power		Remarks
		Theoretical minimum available	Used at present	
MINNEDOSA RIVER:				
15. Two miles from mouth	30	685 *f*	800	Brandon Electric Lt. Co. Not used in winter.
16. Four miles from mouth	40	910 *f*		
17. Eight miles from mouth	45	1,030 *f*		
18. Eighteen miles from mouth	47	1,070 *f*		
19. Thirty-five miles from mouth	20	455 *f*		
20. Minnedosa	25	570 *f*	150	Minnedosa Power Co. Capacity installed, 450 h.p.
BIRDTAIL CREEK:				
21. { At Birtle	24	100 *g*		
21. { ½ mile below Birtle	10	250 *g*		
22. 12 miles above Birtle	10	100 *g*		
SHELL RIVER:				
23. Asessippi	10	227 *g*	50	Flour and grist mill.
VALLEY RIVER:				
24. Sec. 18, Tp. 26, Rg. 19	19	22 *h*		
25. Sec. 16, Tp. 26, Rg. 20	19	22 *h*		
26. Sec. 31, Tp. 25, Rg. 21	56	64 *h*		
27. Sec. 17, Tp. 25, Rg. 22	52	59 *h*		
MOSSY RIVER:				
28. At Winnipegosis	10	74 *e*		
29. At Fork River	10	74 *e*		
WATERHEN RIVER:				
30. Meadow portage	15	5,100 *e*		This site is not on the river, but is on the portage route between the two lakes. The normal head is 18 feet but may be reduced to 15 feet by storms.

Power site	Possible available head in feet	Horse-power		Remarks
		Theoretical minimum available	Used at present	
SWAN RIVER:				
31. At Swan River	14	40 *h*		
DAUPHIN RIVER:				
32. 1½ miles from mouth	16	6,200 *e*		
33. 4 miles from mouth	28	10,800 *e*		
34. 20 miles from mouth	6½	2,500 *e*		
FAIRFORD RIVER:				
35. At Fairford	8	3,100 *e*		
MANIGOTAGAN RIVER:				
36. Wood fall	33	112 *e* 560 *f*		Includes raising natural head 15 feet.
36. Poplar fall	8	27 *e* 136 *f*		
36. 1st rapid above Poplar fall	12	41 *e* 208 *f*		Includes four miles of rapids above.
37. 4th rapid above Poplar fall	30	102 *e* 510 *f*		Includes two miles of rapids above.
38. 12 miles from mouth	12	41 *e* 208 *f*		Includes three miles of rapids above.
38. 15 miles from mouth	18	61 *e* 305 *f*		Includes nine miles of rapids above.
39. Charles fall	34	116 *e* 580 *f*		Includes 1st rapid above.
40. Turtle Cascade	28	95 *e* 477 *f*		
41. 2nd Rapid above Turtle Cascade	21	72 *e* 357 *f*		
41. Caribou fall	27	92 *e* 460 *f*		
PIGEON RIVER:				
42. The Two chutes	6½	1,030 *d*		
43. Sturgeon fall	18	2,860 *d*		Includes rapid below.
44. Lynx rapid	5	800 *d*		
44. Poplar rapid	11½	1,830 *d*		
45. Slide rapid	5½	870 *d*		
45. Lower Caribou rapid	10	1,590 *d*		Includes Caribou and Narrow Rock rapids, 2 miles long.
46. White Rock chute	8½	1,350 *d*		
46. Adjoining rapids	7½	1,190 *d*		250 yards across portage.
47. Rapid, 1¼ m. above last	5	800 *d*		
47. Hawk chutes	17	2,700 *d*		Two chutes 200 yards apart.

Power site	Possible available head in feet	Horse-power: Theoretical minimum available	Horse-power: Used at present	Remarks
PIGEON RIVER—*Continued.*				
48. Long current ...	20	3,200 *d*		Head to be created by dam.
48. High chute	15	2,390 *d*		Includes rapids above.
49. Sturgeon-skin chute	7	1,110 *d*		
49. Peacock rapids ..	21	3,340 *d*		Two short rapids ¼ m. apart.
50. Rapids, 6 miles above last	6	950 *d*		
51. Grass rapid	6	950 *d*		
52. Balsam rapid	10	1,590 *d*		Includes rapid ¼ m. below.
53. Shining fall	29	4,610 *d*		One quarter mile long.
BERENS RIVER:				
54. First rapid	11½	1,180 *d*		
55. Island rapid	17	1,740 *d*		Includes Wolverine and Flat-rock rapids.
56. Roundtent chute and rapid	14	1,430 *d*		½ m. long.
57. Moose portage ...	12½	1,280 d		
58. Oldhouse rapid ...	20	2,050 *d*		Includes Oldhouse and Flag rapids.
59. Sharpstone chute	15	1,530 *d*		Includes Stick, Water and Road rapids.
59. Whitebeaver rapid	10½	1,070 *d*		
60. Smoothrock rapid	7½	770 *d*		Includes rapid ¼ m. above.
61. Sandisland chute	15	1,530 *d*		Includes Liver rapid.
61. Crooked rapid ..	26	2,660 *d*		Includes Child, Wolf and Etomami rapids.
62. Painted Moose chute	13	1,330 *d*		Includes rapid ½ m. below.
63. Crane rapid	7½	770 *d*		
64. Nightowl rapid ..	40	4,100 *d*		Includes rapid above.
65. Little Grand rapid	21	3,820 *d*		
POPLAR RIVER:				
66. First rapid	10	740 *d*		
67. Balsam rapid	12	890 *d*		
68. Whitemud rapid ..	9	660 *d*		
69. Rapid	4	300 *d*		8½ m. above Whitemud rapid.
69. Rapid	9	660 *d*		
69. Rapid	4	300 *d*		
70. Rapid	9	660 *d*		4½ m. below Thunder lake.
71. Rapid	16	910 *d*		2 m. above Thunder lake.
72. Rapid	20	1,135 *d*		4 m. above Thunder lake.

Power site	Possible available head in feet	Horse-power		Remarks
		Theoretical minimum available	Used at present	
BIG BLACK RIVER:				
73. Rapid	13	520 *d*		5 m. above mouth.
73. Cathead rapid	7	280 *d*		
74. High rapid	25	850 *d*		
74. Island rapid	15	510 *d*		
75. Mink rapid	5	170 *d*		
75. Rapid	7	240 *d*		2¼ m. above Mink rapid.
75. Long rapid	57	1,940 *d*		1½ m. long.
75. Rapid	8	250 *d*		3½ m. above Long rapid.
76. Pelican rapid	6	180 *d*		
76. Rapid	4	120 *d*		1½ m. above Pelican rapid.
76. Rapid	9	280 *d*		
76. Skunkfeet rapid	12	310 *d*		
76. Rapid	5	130 *d*		1 m. above Skunkfeet rapid.
76. Rapid	7	180 *d*		
76. Rapid	5	130 *d*		
76. Rapid	5	130 *d*		
77. Adjoining rapids	20	520 *d*		1 m. long.
77. Rapid	10	260 *d*		3 m. above Adjoining rapids.
78. Rapid	6	140 *d*		16 m. above Adjoining rapids.
78. Rapid	5	110 *d*		
78. Rapid	13	300 *d*		
SASKATCHEWAN RIVER:				
79. Grand rapid	80	41,000		
80. Red Rock rapid	15	7,700		
81. Demi-charge rapid	15	7,700		
82. Tobin and Squaw rapids*	35	9,500		6 m. long.
83. Cadotte and Nipawin rapids*	38	10,000		7 m. long.
84. Rapid 4 m. above Cadotte*	10	2,700		2 m. long.
85. Rapid 29 m. above Cadotte*	7	1,900		¾ m. long.
S. SASKATCHEWAN RIVER:				
86. 15 m. below Saskatoon	15	1,700		
BOW RIVER:				
87a. Bassano dam	38		180	Used in operation of dam.
87b. Sou. Alta. Land Co's. dam				
87. Calgary	12		600	Calgary Water Power Co. has steam auxiliary.

* Heads given show natural descents in rapids as obtained from precise levelling by the Department of Public Works; these may not necessarily occur at good power sites, six of which are reported at the following places:

161½ m. below Prince Albert, head of 60 feet possible.
101⅝ m. below Prince Albert, head of 30 feet possible.
84 m. below Prince Albert, head of 40 feet possible.
70 m. below Prince Albert, head of 55 feet possible.
51½ m. below Prince Albert, head of 40 feet possible.
38¾ m. below Prince Albert, head of 40 feet possible.

Power site	Possible available head in feet	Horse-power		Remarks
		Theoretical minimum available	Used at present	
Bow river—*Continued.*				
88. Radnor	44	3,500 *e* 8,000 *f*		
89. Ghost	50	3,970 *e* 9,080 *f*		
90. Mission	47	3,200 *e* 8,000 *f*		
91. Bow Fort	66	4,500 *e* 11,240 *f*		
92. Horseshoe fall	70	4,780 *e* 11,910 *f*	19,500	Calgary Power Co's. hydro-electric plant.
93. Kananaskis fall	70	4,780 *e* 11,910 *f*	12,000	Calgary Power Co's. hydro-electric plant.
94. Banff	64	1,500 *e*		Should not be considered for power purposes on account of the scenic value of the waterfall.
Elbow river:				
95. Sec. 15, Tp. 22, Rg. 6	225	4,500		Other scheme using head of 500 feet also possible.
Kananaskis river:				
96. Upper site	70			Heads would be created by dams in connection with storage project, with the flow subject to storage requirements.
96. Central site	70			
96. Lower site	45			
Cascade river:				
97. Minnewanka	64	1,450 *f*		
Spray river:				
98. Spray fall	50			This site would be flooded out by proposed storage project.
Lake Louise:				
99. Can. Pac. Ry. hotel	130		130	Electric plant.
Red Deer river:				
100. 13 m. below Red Deer	25	570 *e*		These two sites may be combined giving a head of 50 feet.
101. 8 m. below Red Deer	25	570 *e*		
102. At Red Deer	15	340 *e*		

Power site	Possible available head in feet	Horse-power		Remarks
		Theoretical minimum available	Used at present	
BLINDMAN RIVER:				
103. At mouth	30		200	Lacombe electric plant; have steam auxiliary.
BELLY RIVER:				
104. Sec. 33, Tp. 8, Rg. 24		1,200		Approximate estimate.
ST. MARY RIVER:				
105. Sec. 23, Tp. 1, Rg. 25†	238	3,400 *e*		Intake 7 m. distant. See text *re* limitations due to irrigation.
LEE CREEK:				
106. Cardston†	127			Intake 4 m. distant.
TIB CREEK:				
107. Tp. 1, Rg. 28† ..	349			Intake 4 m. distant.
WATERTON RIVER:				
108. Sec. 24, Tp. 1, Rg. 30†	50			
OIL CREEK:				
109. Sec. 23, Tp. 1, Rg. 30	250	392 *j*		
BLAKISTON BROOK:				
110. Sec. 5, Tp. 2, Rg 30†	158			Intake 5 m. distant.
SOUTHFORK RIVER:				
111. Sec. 35, Tp. 6, Rg. 1	45	350 *e*		Heads created by dams.
111. Sec. 6, Tp. 6, Rg. 1	100	800 *e*		Heads created by dams.
111. Sec. 24, Tp. 6, Rg 2	40	320 *e*		Heads created by dams.
MILL CREEK:				
Mountain Mill	30	80 *d*		Head created by dam.
CROWSNEST RIVER:				
112. Near Lundbreck	40	270 *e*		
N. SASKATCHEWAN RIVER:				
113. Crooked rapid* ...	27	3,100		3 m. long.
114. Horseshoe and Stony rapids* ..	15	1,700		1½ m. long.
115. Steep Creek rapid*	18	2,000		2 m. long.
116. Cole fall and rapids	28	3,200		5 m. long, under construction.
117. Rocky rapid (above Edmonton)	85	28,000 *f*		
STURGEON RIVER:				
118. Near mouth	23		250	Fort Saskatchewan electric plant.

† The economic development of these sites is questionable.

Power site	Possible available head in feet	Horse-power		Remarks
		Theoretical minimum available	Used at present	
BRAZEAU RIVER:				
119. 300 ft. below Southesk river ...	62	700 *e* 1,400 *f*		
CLINE RIVER:				
120. Near mouth	100	680		
McLEOD RIVER (tributary of Athabaska river):				
121. Near Edson	30	900 *e*		

(*c*) Shows possible h.p. for the minimum flow of this river, assumed as 26 second-feet.

(*d*) Shows possible h.p. during period from May to November.

(*e*) Shows possible h.p. for the minimum natural flow of the river.

(*f*) Shows possible h.p. for the regulated flow of the river.

(*g*) Shows possible h.p. during the period from May to October.

(*h*) Shows possible h.p. during the period from April to October.

(*i*) Shows possible h.p. during the period from May to October, assumed flow of 45 second-feet.

(*j*) Shows possible h.p. during open water season.

Appendix II

TABLES OF ESTIMATED FLOW AND THEORETICAL HORSE-POWER ON STREAMS IN PRAIRIE PROVINCES, WHERE COMPLETE DATA ON FLOW ARE NOT AVAILABLE

The great difficulty in arriving at figures representing the power possibilities of the different falls and rapids in the northern portion of the Prairie Provinces lies in the fact that very limited data exist upon which to base estimates of the minimum flow of rivers. This minimum flow undoubtedly occurs in winter, but as there is absolutely no information available to serve as a guide in estimating this, the estimates given in the tables are for minimum stages during open river conditions, or, approximately, for that part of the year between the months of May and November. What fraction of this tabulated minimum power is available during the winter would be difficult to say; during a favourable year, possibly one-third could be obtained and probably much less than this during a severe winter.

Wherever possible, the discharge of the river under consideration was measured and the minimum open river discharge estimated by comparing this with the flow in a river where more complete data were available.

Where it was not possible to obtain flow measurements, the open river minimum was estimated from the area of the drainage basin, in some cases dividing the same in several parts and giving each part a different rate of run-off as obtained from the calculated run-off of the nearest basin where measurements had been taken.

Table I. gives the drainage areas at different points of the rivers included in this appendix together with the open river minimum flow at these points, estimated as above described.

Table II. shows the natural heads at the different rapids and falls enumerated with the corresponding open river minimum flow taken from Table I, either directly or by interpolation. The third column gives the theoretical horse-power calculated from the figures in the first two columns.

TABLE I.—DRAINAGE AND ESTIMATED FLOW OF RIVERS

River	Drainage area. Square miles	Estimated low water flow with open river. (May to Nov.) Second-feet
NELSON RIVER:		
Mouth	450,000	51,000
Above Split lake	431,000	50,000
HAYES RIVER:		
Mouth	35,500	
Above Fox river	5,350	1,600
Above Knee lake	2,350	750
At Robinson fall	650	170
ATHABASKA RIVER:		
Mouth	61,000	16,000
Cascade rapid	38,200	11,500
Grand rapid	36,500	11,000
Athabaska	29,200	10,000
Tp. 58, Rg. 21, W. of 5th	12,000	4,000

River	Drainage area. Square miles	Estimated low water flow with open river. (May to Nov.) Second-feet
CLEARWATER RIVER:		
At rapids	5,000	1,120
LESSER SLAVE RIVER:		
Mouth	8,400	1,000
PEACE RIVER:		
Mouth	115,000	25,400
Vermilion chute	101,500	24,000
Peace River Landing	72,100	20,000
Peace cañon	30,100	11,000
NORTH HEART RIVER:		
Mouth	470	25
SMOKY RIVER:		
Mouth	20,000	6,500
SLAVE RIVER:		
Fort Smith	232,000	70,600
BLACK RIVER:		
Mouth	26,400	5,900
Above Black lake	13,000	2,900
Above Waterfound river	6,800	1,500
CREE RIVER:		
Above Pipestone river	4,200	900
GEIKIE RIVER:		
Below Poorfish river	3,200	700
Above Poorfish river	1,500	300
CHURCHILL RIVER:		
Below South Indian lake	97,100	15,400
Above South Indian lake	88,700	14,200
Below Kississing river	82,200	13,300
Below Reindeer river	75,900	12,400
Below Rapid river	51,600	7,200
At Stanley	45,600	6,400
Above Trout river	43,700	6,100
Above Foster river	39,400	5,500
Above Haultain river	33,300	4,700
Above Mudjatik river	29,600	4,100
REINDEER RIVER:		
Mouth	22,600	5,000
Halfway to mouth	21,600	4,800
Above Trout river	19,500	4,200
RAPID RIVER:		
Mouth	5,700	260
FOSTER RIVER:		
Mouth	2,900	650
Above Sandy river	1,800	400
MUDJATIK RIVER:		
Mouth	2,300	500
Above Heddery river	1,300	300
BEAVER RIVER:		
Grand rapids	14,000	650
METHY RIVER:		
Above Whitefish river	1,000	50

TABLE II.—ESTIMATED WATER-POWERS

Power site	Head (in feet)	Estimated low water flow during open season (May to Nov.) Second-feet	Available theoretical h.p. (May to Nov.)	Remarks
NELSON RIVER*:				
122. 1st Last Limestone rapid† ..	6	51,000	34,700	¾ m. long.
2nd Last Limestone rapid† ..	15	51,000	87,000	1 m. long.
3rd Last Limestone rapid† ..	10	51,000	57,900	¾ m. long.
4th Last Limestone rapid† ..	10	51,000	57,900	1½ m. long.
123. Lower Limestone rapid†	8	51,000	46,300	⅛ m. long.
Upper Limestone rapid	25	51,000	144,700	¾ m. long.
124. Lower Long-spruce rapid ..	52	51,000	301,000	4 m. long.
Upper Long-spruce rapid ..	40	51,000	231,500	2 m. long.
125. 1st Kettle rapid	40	51,000	231,500	3 m. long.
2nd Kettle rapid	21½	51,000	124,500	½ m. long. H.B. Ry. crossing.
3rd Kettle rapid	17	51,000	98,500	100 yards long.
126. 1st Gull rapid ..	20	51,000	115,800	⅓ m. long. Head could be raised to 30 feet.
2nd Gull rapid ..	20	51,000	115,800	500 yards long.
3rd Gull rapid ..	21	51,000	121,500	350 yards long.
4th Gull rapid ..	17	51,000	98,500	⅜ m. long.
127. Overfall rapid‡ ..	25	51,000	144,700	½ m. long.
128. Chain-of-islands chute	4½	50,000	25,500	300 yards long. Possible head 8 feet.
129. Grand rapid	20	50,000	113,500	160 yards across portage. Possible head 26 feet.
130. Manitou rapid ...	25	50,000	142,000	Head created by dam.
131. Red Rock rapid ..	12	50,000	68,000	900 yards long.
132. Over-the-hill rapid	9½	50,000	54,000	Possible head 13 feet.
133. Bladder rapid	11½	50,000	65,500	900 yards long.
134. Whitemud fall ..	30	50,000	170,000	500 yards across portage.
135. Ebb-and-flow rapid	9½	50,000	54,000	
136. Whiskey Jack portage	35	50,000	200,000	

* The estimated flow and h.p. given for the Nelson river are based on a flow of 50,000 second-feet just below lake Winnipeg.

† Not favourable for development.

‡ Also called Birthday rapid.

Power site	Head (in feet)	Estimated low water flow during open season (May to Nov.) Second-feet	Available theoretical h.p. (May to Nov.)	Remarks
HAYES RIVER:				
137. 23 m. below "The Rock"	35*	1,600	6,350	Heads to be created by dams; river about 250 ft. wide.
138. 7 m. below "The Rock"	35*	1,600	6,350	
139. The Rock fall	5	1,500	850	
140. Whitemud fall ...	5	1,500	850	
141. Rapid, 18 m. above "The Rock" ...	5	1,300	740	
141. Chute, 20 m. above "The Rock" ..	11	1,300	1,620	200 yards long, including rapids.
142. Rapid, 22 m. above "The Rock" ..	10	1,300	1,480	450 yards long.
142. Muskeg rapid ...	8	1,200	1,090	300 yards long.
143. Chute, 2½ m. above Muskeg rapid	10	1,200	1,360	250 yards long.
143. Rapid, 5½ m. above Muskeg rapid	5	1,200	680	110 yards long.
144. Yellowmud rapid	5	1,000	570	200 yards long.
144. Lower Drum rapid	10	1,000	1,130	500 yards long.
144. Middle Drum rapid	7	1,000	800	200 yards long.
144. Upper Drum rapid	12	1,000	1,360	320 yards long, including rapids below.
145. Trout fall	11	750	940	250 yards long, including rapids below.
145. Rapid, 1 m. above Trout fall	8	750	680	300 yards long.
146. Rapid, 2½ m. above Oxford lake	6½	350	260	100 yards long.
147. Rapid, 3 m. above Pine lake	7	200	160	200 yards long.
148. Rapid, 8 m. above Pine lake	5	200	110	Head could be increased by dam ¼ m. below in cañon-like part of river.
149. Robinson fall	56	170	1,080	¾ m. across portage.

* Aneroid observations show a descent of some 285 feet on the Hayes river between "The Rock" and the mouth of the Fox river, a distance of thirty-five miles. Heads would have to be created by dams; the height of the two given here are only arbitrarily chosen and other similar ones are possible in this reach. See general description of the river, p. 115.

Power site	Head (in feet)	Estimated low water flow during open season (May to Nov.) Second-feet	Available theoretical h.p. (May to Nov.)	Remarks
ATHABASKA RIVER:				
150. Mountain rapid	8	11,500	10,500	1 m. long.
150. 5 m. above Mountain rapid	15	11,500	19,500	4 m. long.
151. Cascade rapid	7	11,500	9,000	1 m. long.
151. Little Cascade rapid	10	11,500	13,000	2 m. long.
151. Rock rapid	12	11,500	15,500	1½ m. long.
151. Crooked rapid	13	11,500	17,000	1½ m. long.
152. Long rapid	28	11,500	36,500	3 m. long.
152. Middle rapid	20	11,500	26,000	1½ m. long.
152. Boiler rapid	25	11,500	32,500	3 m. long.
153. Brûlé rapid	8	11,500	10,500	½ m. long.
154. Rapid at Pt. Brûlé	10	11,300	12,500	2 m. long.
154. Rapid 2½ m. above Pt. Brûlé	10	11,300	12,500	1 m. long.
155. Grand rapid	54	11,000	67,000	3½ m. long, including rapids immediately above and below.
156. Major rapid	6	11,000	7,500	½ m. long.
157. 7 m. below Stony rapid	8	11,000	10,000	1 m. long.
158. Stony rapid	5	11,000	6,000	⅓ m. long.
159. Pelican rapid and rapid above	17	11,000	21,000	2½ m. long.
160. 7 m. below Lesser Slave river	10	9,500	10,500	⅜ m. long.
161. Tp. 58. Rg. 21, W. of 5th	80	4,000	36,000	Over 1 m. long.
162. Tp. 56. Rg. 21, W. of 5th	42	4,000	19,000	
163. Athabaska fall	20	400	900	
CLEARWATER RIVER:				
164. Cascades rapid	16	1,120	2,000	1 m. long.
164. Le Bon rapid	31	1,120	3,900	1½ m. long.
164. Bigstone rapid	7	1,120	900	⅓ mile long.
165. Aux Pins rapid	21	1,120	2,700	½ m. long.
166. Whitemud rapid	41	1,120	5,200	¼ m. long. Head can easily be raised to 50 ft., increasing h.p. in proportion.
LESSER SLAVE RIVER:				
167. 2½ m. from mouth*	8	2,200	2,000	1¼ m. long.
167. 7½ m. from mouth*	6	2,200	1,500	1 m. long.
167. 9 m. from mouth*	15	2,200	3,700	2½ m. long.

* These descents are taken from a profile plotted from levels taken by the Department of Public Works, and show the steepest portions of a series of rapids extending over a distance of nearly twenty miles from the mouth of the Lesser Slave river, with a total descent of 80 feet.

Power site	Head (in feet)	Estimated low water flow during open season (May to Nov.) Second-feet	Available theoretical h.p. (May to Nov.)	Remarks
LESSER SLAVE RIVER—*Con.*				
168. 12½ m. from mouth*	13	1,000	1,480	1 m. long.
168. 14½ m. from mouth*	8	1,000	910	1 m. long.
STONY RIVER:				
169. Stony fall	75	200	1,700	
McLEOD RIVER (See App. I p. 280)				
PEACE RIVER:				
170. Boyer or Little rapid†	8			¾ m. long.
171. Vermilion fall and rapid	26	24,000	71,000	1¾ m. long.
172. Peace Cañon rapids‡	225	11,000	282,000	18 m. long following river; 11 m. across portage.
SLAVE RIVER**:				
173. Drowned rapid	13	70,600	104,000	½ m. long.
173. Pelican rapid	10	70,600	80,000	3 m. long.
173. Mountain rapid	25	70,600	200,000	1 m. long following river; ⅛ m. across portage.
174. Rapid above Mountain rapid	42	70,600	336,000	2 m. long.
174. Cassette rapid	27	70,600	216,000	1 m. long.
BLACK RIVER§:				
175. 8 m. above mouth	8	5,900	5,400	2,000 ft. long.
176. Below Middle lake	160	5,900	107,000	2 m. long.
177. Elizabeth fall	120	5,900	80,000	3½ m. long.
178. 8 m. below Porcupine river	25	2,900	8,200	3,000 ft. long.
179. North rapid	15	2,900	5,000	1 m. long.
180. Hawkrock rapid	10	2,900	3,300	
181. Brink rapid	25	2,900	8,200	

* These descents are taken from a profile plotted from levels taken by the Department of Public Works, and show the steepest portions of a series of rapids extending over a distance of nearly twenty miles from the mouth of the Lesser Slave river, with a total descent of 80 feet.

† Not suitable for development.

‡ In British Columbia.

** The five rapids enumerated under the Slave river are known collectively as the Fort Smith rapids; they extend from Smith Landing to Fort Smith, a distance of some 16 miles, and the total descent between these two points, including swift waters between rapids, would be in the neighbourhood of 135 feet, with 1,080,000 h.p.

§ The descents in the rapids and falls on this river are taken from a report by J. B. Tyrrell of the Geological Survey (1896).

Power site	Head (in feet)	Estimated low water flow during open season (May to Nov.) Second-feet	Available theoretical h.p. (May to Nov.)	Remarks
BLACK RIVER—*Con.*:				
182. Manitou fall	15	2,900	5,000	350 ft. long.
Thompson rapid .	30	2,900	10,000	
2 m. above Thompson rapid	8	2,900	2,600	
183. Above Kosdaw lake	20	2,900	6,600	1 m. long.
184. Above Waterfound river	10	1,500	1,700	
185. Above Crooked lake	12	1,500	2,000	1,000 ft. long.
1½ m. above Crooked lake	14	1,500	2,400	In two rapids.
Below Hatchet lake	18	1,500	3,100	
CREE RIVER*:				
186. 9 m. above Badwater river	40	900	4,100	3 m. long.
187. Hawk rapid	35	900	3,600	2 m. long.
GEIKIE RIVER*:				
188. Below Poorfish river	45	3,200	14,000	1 m. long.
189. 2½ m. above Poorfish river	35	1,500	6,000	½ m. long.
4 m. above Poorfish river	35	1,500	6,000	2 m. long.
190. Above Whitespruce rapid ..	20	1,500	3,400	In two rapids.
Whitespruce rapid	18	1,500	3,100	¾ m. long.
191. 5 m. below Whitespruce rapid ...	30	1,500	5,100	
192. 2nd rapid below Whitespruce rapid	12	1,500	2,000	
193. 5 m. above Big Sandy lake	15	1,500	2,500	
CHURCHILL RIVER†:				
194. Below Southern Indian lake	18	15,400	31,000	
195. Above Southern Indian lake	2	14,200	3,200	

*The descents in the rapids and falls on these rivers are taken from a report by J. B. Tyrrell of the Geological Survey (1896).

†The descents for numbers 194-213 are taken from observations by Wm. McInnes of the Geological Survey (1906).

Power site	Head (in feet)	Estimated low water flow during open season (May to Nov.) Second-feet	Available theoretical h.p. (May to Nov.)	Remarks
CHURCHILL RIVER—*Con.*:				
196. Leaf rapid	8	14,200	13,000	
197. Above Leaf rapid	2	14,200	3,200	
198. Granville fall ...	25	13,300	38,000	
198. Above Granville fall	5	13,300	7,600	
199. Rapid	19	13,300	29,000	Portage, 8 chains long.
199. Rapid	15	13,300	23,000	Portage, 3 chains long.
200. Below Pukkatawagan lake	4	12,400	5,600	
201. Rapid	2	12,400	2,800	
202. Redstone rapid	15	12,400	21,000	
203. Below Loon river	6	12,400	8,500	
204. Two rapids	7	12,400	10,000	
205. 1st rapid above Nemei river ..	14	12,400	19,700	
205. 2nd rapid above Nemei river ..	11	12,400	15,500	
205. 3rd rapid above Nemei river ..	8	12,400	11,200	
205. 4th rapid above Nemei river ..	11	12,400	15,500	
206. Knife rapid	11	12,400	15,500	
206. Rapid	8	12,400	11,200	
206. Above Knife rapid	5	12,400	7,000	
207. Wintego	9	12,400	12,700	
207. 1st rapid above Wintego	3	12,400	4,200	
207. 2nd rapid above Wintego	25	12,400	35,000	
208. 3rd rapid above Wintego	9	12,400	12,700	
208. 4th rapid above Wintego	4	12,400	5,600	
209. Atik rapid	15	12,400	21,000	
209. Kettle fall	17	7,200	14,000	
210. Grand rapid	16	7,200	13,000	
211. Keg rapid	7	7,200	5,700	
211. Island rapid	9	7,200	7,300	
212. Pine rapid	7	7,200	5,700	
213. Grave rapid	4	6,400	4,600	
214. Otter fall†	20	6,400	14,500	½ m. long.
215. Birch fall†	8	6,100	5,500	800 ft. long.
216. Above Black Bear Island lake†	6	6,100	4,100	350 ft. long.

† The descents in these are taken from a report by T. Fawcett of the Department of Interior (1888).

Power site	Head (in feet)	Estimated low water flow during open season (May to Nov.) Second-feet	Available theoretical h.p (May to Nov.)	Remarks
CHURCHILL RIVER—*Con.*:				
217. Lower Needle fall‡	4	5,500	2,500	250 ft. long.
218. Pelican rapid‡	8	4,700	4,300	1,700 ft. long.
219. Rapids above Mudjatik river	5	4,100	2,300	
	8	4,100	3,700	
	6	4,100	2,800	
REINDEER RIVER‡:				
220. Deer rapid	5	5,000	2,800	
221. Steep Hill rapid	20	4,800	11,000	
222. Devil rapid	9	4,200	4,300	
223. Whitesand rapid	20	4,200	9,500	
223. Rock rapid	10	4,200	4,800	
RAPID RIVER:				
224. Fall and rapid above mouth	50	260	1,500	Includes a vertical fall of 30 ft.
FOSTER RIVER‡:				
225. 6 m. above mouth	25	650	1,800	900 ft. long.
226. 10 m. below Sandy creek	15	650	1,100	1,800 ft. long.
227. 3 m. below Sandy creek	5	650	400	400 ft. long.
228. 30 m. above Sandy creek	10	400	500	
MUDJATIK RIVER‡:				
229. Bear rapid	2	500	100	300 ft. long.
230. 5 m. above Bear rapid	12	500	700	
231. 10 m. above Bear rapid	10	500	600	
232. Grand rapid	8	300	300	270 ft. long.
232. ¼ m. above Grand rapid ..	6	300	200	
233. 3 m. above Grand rapid	5	300	170	300 ft. long.
	5	300	170	300 ft. long.
	3	300	110	150 ft. long.

‡The descents in these falls and rapids are taken from a report by J. B. Tyrrell of the Geological Survey (1896).

Power site	Head (in feet)	Estimated low water flow during open season (May to Nov.) Second-feet	Available theoretical h.p. (May to Nov.)	Remarks
BEAVER RIVER:				
234. Grand rapid	27	650	2,000	2 m. long.
235. Rapids above Grand rapid*..........	†		1,500	Utilization of total power conjectural.
LA PLONGE RIVER:				
Beauval	10			Saw mill and electric light for Beauval mission.
METHY RIVER:				
236. Above Whitefish river†............	40†	50	230	Utilization of total power conjectural.
237. 6 m. below Methy lake	10	50	60	⅔ m. long.

*Succession of rapids extending over a distance of some 22 miles, with descents of from 2 to 6 feet; the h.p. given is a rough estimate of the total power available in these.

†Succession of rapids extending over a distance of 6 miles, the greatest descent in any one rapid being 5 feet.

Appendix III

TABLE SHOWING THE DESCENTS ON STREAMS WHERE LACK OF INFORMATION PREVENTS ESTIMATING FLOW

NOTE:—There are other rapids and falls on some of the rivers given, but definite figures are only available as enumerated below. See general description of rivers in the first part of the report.

Power site	Head in feet	Remarks
GRASS RIVER:		
238. Lynx fall	43	
239. Sasagiu rapid	12	
240. Wapishtigau fall	40	
241. Wekusko fall	45	
242. 3 m. below Reed lake	3	
243. 5 m. below Elbow lake	6	
4 m. below Elbow lake	15	160 yards long.
BURNTWOOD RIVER:		
244. Manasan fall	20	
245. Wapishtigau fall	15	
Kepuche rapid	3	
Waskatigau rapid	30	400 yards long.
246. Taskinigup rapid	50	320 yards long.
Waskwatin fall	20	220 yards long.
247. Gate rapid	17	
Leaf rapid	8	
One mile above Leaf rapid	8	
Two miles above Leaf rapid	7	
248. 2nd Driftwood rapid	5	
1st Driftwood rapid	4	
249. Clay rapid	25	
Flathill rapid	10	
Eagle rapid	8	
Carrot rapid	8	
DUBAWNT RIVER:		
250. Foot of Schultz lake	5	
251. 2 m. below Lady Marjory lake	20	300 yards long.
252. 11 m. below Wharton lake	20	Portage at lower part 400 yards long.
253. 3 m. below Wharton lake	6	
1 m. below Wharton lake	15	
254. 1¼ m. above Wharton lake	10	250 yards long.
255. 1 m. below Grant lake	100	2 miles long.
256. Foot of Nicholson lake	40	2½ miles long.
257. 10 m. above Carey lake	15	
258. Foot of Carey lake	55	3 miles long.
259. Foot of Barlow lake	12	
260. 3 m. above Hinde lake	20	
261. 11 m. above Hinde lake	12	

Power site	Head in feet	Remarks
Kazan river:		
262. 64 m. below Angikuni lake	10	140 yards long.
263. 47 m. below Angikuni lake	20	½ m. long.
264. 30 m. below Angikuni lake	60	1½ m. long.
265. { 2 m. above Ennadai lake	15	
265. { 5 m. above Ennadai lake	10	
266. { 9 m. below Kasba lake	5	
266. { 8 m. below Kasba lake	6	
267. 4 m. below Kasba lake	15	
Ferguson river:		
268. 3 m. above mouth	10	Short rapid.
269. 2 m. below Kaminuriak lake ...	15	Irregular cascade.
Hay river:		
270. Alexandra fall	135	Two sheer descents of 85 feet and 50 feet, one mile apart, with three miles of rapids below.
Frances river:		
271. Middle cañon	30	3 miles long. Rocky banks up to 300 feet high.
272. Upper cañon	30	1¼ miles long. Rocky banks 5 to 200 feet high.
Lewes river:		
273. Miles cañon and Whitehorse rapid	49	Cañon, 100 feet wide, banks 50 feet high. At rapid, banks are 20 feet and under. Total length of cañon and rapid, 2¾ miles.
Pelly river:		
274. Hoole cañon	20	Portage ½ mile long, ¾ mile by river.
275. Rapid below Hoole river	10	200 yards long.
Coppermine river:		
276. Bloody fall	15	300 yards long. High sandstone banks.
Hood river:		
277. Rapid 10 m. above mouth	18	
278. Wilberforce fall	250	In two falls close to each other.
Backs river:		
279. Rapid below lake Franklin	20	
280. Foot of Beechey lake	60	Series of cascades two miles long.

Power site	Head in feet	Remarks
LOCKHART RIVER:		
281. Parry fall	85	
282. Fall below Anderson fall	10	
282. Anderson fall	47	
282. Fall above Anderson fall	25	
283. Harvey fall	50	
284. Casba fall	15	
HOARFROST RIVER (tributary of Great Slave lake):		
285. Beverley fall	60	
286. Below Cook lake	20	
HANBURY RIVER:		
287. Fall below Helen fall	10	
287. Helen fall	60	
288. Ford fall	60	
288. Dickson cañon	213	Portage 2 miles long.
288. Macdonald fall	50	
289. Fall	7	
290. Rapid	60	Portage ½ mile long.
290. Grove rapid	45	Portage ⅞ mile long.
290. Rapid	30	Portage 400 yards long.
290. Timber rapid	10	Portage 500 yards long.
TYRRELL RIVER:		
291. Fall	50	

Appendix IV

UTILIZED WATER-POWERS IN THE YUKON

Power site	Head in feet	Power used at present (h.p.)	Remarks
LITTLE TWELVEMILE RIVER:			
292. Near Twelvemile river	710	2,700	Yukon Gold Co.
NORTH FORK KLONDIKE RIVER:			
293. Near Klondike river	228	10,000	Canadian Klondike Power Co.

Appendix V

MONTHLY PRECIPITATION (in inches)—MANITOBA
(Taken from reports of the Meteorological Service)

Place	Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Winnipeg	1907	2.12	.27	1.12	.99	.97	1.54	3.98	3.90	.69	.40	.72	.18
	1908	.44	1.80	1.83	1.75	3.01	3.11	1.76	2.44	1.89	2.21	.55	.65
	1909	.73	.76	2.67	1.58	1.25	1.54	3.84	4.75	.60	.52	.89	3.99
	1910	.25	1.56	1.65	1.49	1.65	2.38	.80	2.14	2.75	1.08	1.27	1.87
	1911	.43	.71	.28	2.57	6.38	2.27	2.96	2.33	2.43	1.84	.59	.59
	1912	.30	.18	.30	2.25	3.59	.91	6.11	1.64	5.49	1.15	.11	.78
	1913	.75	.61	.36	.41	.53	3.27	2.09	4.71	1.27	.77	.75	.26
	1914	.79	.83	.59	.75	1.65	1.46	7.14	2.05	2.28	2.22	.72	1.40
	Average for 40 years	.97	.69	1.25	1.54	2.01	3.44	3.33	2.34	1.92	1.52	1.08	.72
Morden	1907	2.36	.93	1.38	1.51	.76	1.23	1.47	1.63	1.08	.69	.73	.27
	1908	.39	2.50	1.80	1.71	2.57	3.60	.71	2.27	.61	2.12	1.07	.98
	1909	.70	.59	.90	1.98	4.06	1.62	3.62	.96	.38	.59	.90	1.97
	1910	.22	.70	1.73	1.71	1.12	1.18	1.14	1.44	2.21	1.12	1.05	1.41
	1911	1.26	.97	.21	1.86	3.35	1.31	.98	2.04	1.45	1.60	1.20	1.24
	1912	.85	.85	.05	1.60	2.02	.45	4.58	2.46	3.93	1.21	*	.75
	1913	1.20	1.40	1.50	.57	.54	.83	1.01	3.59	1.19	1.10	.25	.20
	1914	2.00	2.60	1.00	1.22	1.51	1.71	1.31	1.17	2.20	.51	2.10	1.30
	Average for 17 years	.83	.71	1.22	1.11	2.02	3.20	2.84	2.03	1.76	1.23	1.04	.82
Brandon	1907	2.45	.25	1.55	1.05	2.75	2.51	2.45	6.24	.82	.20	.35	.20
	1908	.30	.75	1.40	1.24	2.14	2.97	2.22	2.09	1.73	.77	.68	1.20
	1909	1.10	.90	1.30	1.11	2.53	2.62	3.20	.38	1.03	.47	1.57	2.70
	1910	.20	.30	1.61	.54	1.06	2.09	2.00	1.04	1.91	.03	2.10	1.10
	1911	1.90	.70	.10	.30	2.68	1.97	2.91	5.84	1.43	1.60	.60	
	1912	.30	.30	.27	1.56	2.94	.24	6.46	1.17	3.46	.24	.10	1.00
	1913	1.10	.60	.50	.35	1.04	2.34	1.70	3.56	.68	.73	.29	.00
	1914	1.65	.30	.10	2.52	2.28	2.24	1.87	1.02	2.47	1.54	.70	10
	Average for 27 years	.83	.86	.86	.75	1.30	3.03	2.33	1.89	1.25	.66	.81	.59
Minnedosa	1907	1.23	.30	.86	1.07	.57	3.98	2.76	3.27	1.39	.36	.36	.26
	1908	.31	.59	.72	1.31	2.09	2.68	3.20	2.83	1.53	.48	.74	.28
	1909	.45	1.85	.71	1.60	1.53	1.84	3.11	1.23	1.13	.45	.72	1.22
	1910	.03	.30	.82	1.46	1.07	2.63	1.60	1.73	1.48	.18	1.52	.76
	1911	1.19	.94	.23	.62	2.87	3.05	2.05	5.42	2.77	1.86	.83	.47
	1912	.49	.46	.69	1.26	3.09	.31	3.93	2.42	3.13	.27	.29	.84
	1913	.83	.88	.38	.31	1.33	2.93	3.87	2.51	.95	.66	1.07	.15
	1914	1.76	.30	.39	1.64	3.15	1.39	2.23	.82	2.13	1.44	1.87	.33
	Average for 30 years	.88	.57	.80	.88	1.85	3.41	2.64	2.72	1.52	1.05	1.02	.62

* Trace of precipitation, too small to measure.

MONTHLY PRECIPITATION (in inches)—MANITOBA.—*Continued*

Place	Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Dauphin	1907	.90		.60	.00	.99	2.08	2.83	6.79	1.13	.70	.20	.90
	1908												
	1909												
	1910												
	1911					4.89	1.60	2.36	3.18	2.45	1.65		.60
	1912			.30	.30	2.00	2.03	6.01	2.54	6.95	.50		.80
	1913	1.20	1.40	.40	.00	.53	2.19	4.11	2.05	1.10	.12	.60	*
	1914	1.30	.40	.30	.59	3.17	.66	3.27	2.17	1.73	1.62	1.00	.20
Berens River	1908	.25	.80	.80	.52	1.45	5.06		3.36	1.34	.45	2.15	1.60
	1909	1.10	.55	.50	1.70	.95	.82	.34	1.80	1.20	.91	.96	3.60
	1910	.00	.20	4.16	1.70	1.98	2.30	1.50	2.15	2.40	.30	2.60	1.35
	1911	.40	1.00	.40	1.30	3.56	.80	4.89	1.24	2.49		2.65	2.90
	1912		.40	1.60	.65	1.14	1.11				2.50	.40	.90
	1913	1.40	.30	.00	.05	2.87	1.35	1.55			2.33	.95	
	1914	1.20		.43	.60	.25						2.05	.40
	Average for 7 years	.72	.54	1.13	.93	1.74	1.90					1.68	1.79
York Factory	1908	.90				.20	.17	.87	2.51	.66	.55	.75	.15
	1909	.70	.30				.45	1.90	1.62	3.28	.95	*	*
	1910	*	*	*	*	.04	.30			.25	.70	*	*
	1911												
	1912										3.0		1.20
Norway House	1908						4.01	.46	5.66	.48	.91	1.60	.92
	1909	1.27			1.60		3.52	.53	.48	3.64	.91	1.88	2.02
	1910	.40	.30	2.20		.42	.57	.28	3.04	2.22	.11		
	1911		.13		.60	.40	2.61	.85		1.04	2.50		
	1912					3.61	.63	2.53	.60	1.33	.30	.80	
	1913	.10	.10	.10				1.97	3.76				
The Pas	1911	.40	.20	.52	2.64	1.21	2.23	4.67	2.35	1.92	.45	2.30	.70
	1912	.02	.14	.49	.32	.73	1.22	4.39	2.61	3.54	.82	1.55	.60
	1913	1.17	.27	.06	.76	1.51	3.22	2.42	2.92	.99	.61	.33	.13
	1914	1.40	.28	.62	1.02	2.80	.57	2.78	1.44	.65	1.98	1.20	.27

* Trace of precipitation, too small to measure.

MONTHLY PRECIPITATION (in inches)—SASKATCHEWAN

Place	Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov	Dec.
Estevan	1907	2.45	.40	1.75	.40	.61	.89	2.31	4.92	.37	.10	*	1.25
	1908	.30	1.00	1.00	1.03	3.17	3.94	2.01	2.48	1.41	1.45	.30	.30
	1909	.35	.15	.10	1.60	5.64	1.29	1.05	.78	.51	.12	.40	.50
	1910	.45	.20	2.23	1.53	2.02	3.54	.90	2.03	.45	.14	1.57	.40
	1911	.80	.40	.20	.50	2.40	2.04	2.60	3.35	1.29	1.49	.27	.20
	1912	.20	*	.40	.99	4.85	.74	2.16	2.63	1.98	.86	.20	.60
	1913	.20	*		.35	1.19	5.60	.90	1.68	1.62	.74	.20	.00
	1914	1.10		.90	.30	1.62	4.85	1.57	2.17	.39	.30	.40	.22
	Average for 12 years	.66	.57	1.17	.87	2.68	2.15	1.58	2.57	1.35	.54	.39	.78
Grenfell	1907	.50	.20	1.20	1.94	.79	5.72	1.41	2.68	1.49	.07	.40	.60
	1908	.30	2.00	2.05	2.20	1.62	2.10	1.55	1.46	0.98	1.29	.70	.60
	1909	.70	.80	1.18	2.85	2.81	1.00	7.09	2.45	.29	.53	1.95	.80
	1910	.40	.85	2.65	2.26	3.07	4.65	1.59	1.81	.43	.22	1.30	.80
	1911	2.10	.30	.28	.53	3.01	3.18	2.49	2.42	3.31	1.89	1.93	.40
	1912	.50	.30	.70	1.01	4.83	.56	3.31	1.85	4.61	.14	.55	.90
	1913	1.15	1.10	1.40	.38	2.24	5.51	2.26	3.64	1.50	1.62	1.00	
	1914	1.70	.12	1.20	3.07	2.76	2.63	3.14		.45	1.58	1.71	.45
	Average for 22 years	.24	.32	1.09	1.08	1.94	3.26	2.95	2.34	1.57	.72	.98	.73
Kamsack	1910	.40	.35	.85	.20	2.66	4.18						
	1911												
	1912									2.06	.47	.20	.40
	1913	1.45	1.60	.55	.10	.52	2.91	5.10	2.47	.60	.44		
	1914				.29	1.72	.98	.58	.73	.95	.91		
Regina	1907	.70	.03	.30	.75	.85	4.52	2.10	3.26	.90	.06	.17	.16
	1908	.16	.48	.48	.99	.98	5.33	1.55	1.44	.18	1.37	.29	.25
	1909	.13	.28	.59	1.34	2.96	2.24	7.52	3.26	.14	.50	.67	.65
	1910	.14	.28	.98	.37	2.88	3.15	.96	2.90	.27	.24	.77	.77
	1911	.63	.24	.40	.48	3.63	2.89	3.42	2.90	.57	1.56	1.38	.45
	1912	.14	.11	.09	.53	2.17	1.91	1.37	1.87	1.57	.29	.09	.55
	1913	.30	.11	.49	.03	.95	3.72	2.82	4.09	.47	.72	.15	.10
	1914	.84	.25	.74	.30	2.22	3.99	1.29	.81	.29	.92	.24	.09
	Average for 27 years	.38	.32	.47	.74	2.00	3.29	.97	1.66	1.01	.69	.52	.61
Chaplin	1907	3.20	1.10	1.80	1.65	1.89	3.36	3.75	5.28	.65	.01	.10	1.20
	1908	.50	1.20	1.60	.88	.99	4.06	0.49	1.99	0.46	1.35	.70	.71
	1909	.90	.70	.60	.74	2.65	4.02	6.50	1.67	1.17	.33	1.25	1.60
	1910	.03	.08	1.69	.22	2.20	2.65	1.04	2.53	1.00	.15	.10	1.60
	1911	.27	.11	.15	2.33	3.59	3.82	2.05	2.81	1.05	1.20	.07	.60
	1912	.09	.07	.04	.21	3.91	1.91	2.87	3.50	2.08	.61	.10	.04
	1913	.08	.06	.50	.22	.48	2.13	2.25	2.88	.27	.82	.02	.02
	1914	1.05	.45	.85	1.03	.36	3.28	.39	.92	.96	2.02	.98	.45
	Average for 26 years	.72	.47	.70	1.24	2.14	3.37	2.25	2.52	.85	.70	.19	.51

* Trace of precipitation, too small to measure.

MONTHLY PRECIPITATION (in inches)—SASKATCHEWAN.—*Continued*

Place	Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Saskatoon	1907	1.20	*	.80	.30	.55	2.12	1.48	2.58	1.04	.01	.05	.25
	1908	.10	.75	.63	.64	.65	5.48	1.22	2.00	0.33	1.65	.25	.45
	1909	.80	.32	.45	.15	2.39	1.76	6.14	.23	.57	1.54	.77	.75
	1910	.30	.20	.40	.25	.79	2.26	2.18	2.19	1.55	.27	.15	.50
	1911	2.60	.40	.30	1.54	2.40	5.07	1.87	3.18	.56	.00	.70	.80
	1912			.60	.06	3.07	3.43	2.71	2.74	2.96	.27	.45	.60
	1913	1.00	1.00	.25	.28	.35	2.92	2.14	2.58	1.69	.49	.65	.10
	1914	.90	.40	.48	.40	1.65	1.88	.85	.41	1.44	2.60	1.05	.60
	Average for 18 years	.49	.42	.59	.37	1.59	2.51	2.54	2.17	1.46	.72	.50	.64
Prince Albert	1907		.46	1.82	.55	1.69	2.53	2.21	4.13	1.08	.56	.15	
	1908	.40	2.15	.35	2.82	.58	7.36	.36	3.03	0.53	1.63	1.13	1.81
	1909	.77	.75	.55	1.02	.58	4.34	3.90	1.18	1.37	.97	1.40	1.90
	1910	.81	.45	.31	.40	.69	.34	1.37	.69	.79	.16	1.21	.18
	1911	2.00	.41	.11	.79	1.75	3.09	1.98	2.99	1.77	.04	2.26	1.10
	1912		.10	1.03	.25	1.79	2.77	5.31	2.75	2.16	.56	.90	1.07
	1913	.80	.80	1.20	.17	.79	1.98	4.76	3.59	2.53	.88	.31	.11
	1914	.71	.06	.61	1.34	2.54	2.01	1.15	.80	1.12	1.37	1.10	.56
	Average for 28 years	.87	.73	1.03	.82	1.54	2.63	2.42	2.53	1.44	.86	.97	.76
Battleford	1907	.13	.07	.52	.13	.30	1.54	2.26	2.58	2.13	.04	.01	.40
	1908	.46	1.01	1.66	.31	1.21	7.60	0.65	1.58	1.23	.85	.85	.04
	1909	.22	.02	.20	.40	1.49	2.88	3.57	.33	.58	.63	.82	.70
	1910	.20	.10	.20	.19	2.35	1.53	.96	1.08	1.46	.18	.30	.20
	1911	1.30	.50	.10	.50	2.60	7.14	3.39	2.23	1.29	.11	.81	.50
	1912	.02	.01	.20	.03	1.80	1.18	5.35	2.74	2.06	.55	.40	.50
	1913	.50	.20	.30	.00	.46	1.70	3.56	2.64	1.07	.18	.10	*
	1914	.70	.40	.80	.54	2.86	2.47	1.28	2.30	3.97	2.26	.74	.82
	Average for 23 years	.46	.43	.66	.41	1.69	3.47	2.11	1.98	1.26	.44	.49	.39

* Trace of precipitation, too small to measure.

MONTHLY PRECIPITATION (in inches)—ALBERTA

Place	Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Medicine Hat	1907	.75	.25	.51	.30	.65	1.69	.92	.62	1.01	.00	.01	.15
	1908	.10		.45	.05	2.98	1.66	1.85	1.34	*	1.22	*	.12
	1909	.35	.35	.20	.30	2.18	2.67	1.69	.20	.42	.13	.52	.79
	1910	.29	.45	.02	.20	.49	.29	1.63	2.24	.54	.30		
	1911			.32	1.49	1.84	3.60	1.65	2.20	1.75	.45	2.20	.54
	1912	.70	.18	.31	.94	1.63	1.19	.98	1.58	1.34	.88	.29	.36
	1913	.41	1.11	1.06	.97	1.06	3.72	1.35	2.43	.80	.41	.10	.20
	1914	1.22	.80	.59	*	.55	2.00	.34	.66	1.40	3.48	.23	90
	Average for 29 years	.60	.61	.67	.59	1.85	2.63	1.87	1.48	1.11	.52	.75	.51
Macleod	1907	.30	.30	1.19	.91	1.30	3.57	.74	1.59	1.96	*	.05	.45
	1908	.51	.78	1.77	.34	4.71	6.83	0.77	0.59	.89	.79	.10	.05
	1909	.74	.50	.65	1.33	3.51	3.02	3.19	.11	.19	.20	.52	.92
	1910	.38	1.75	.16	.16	.99	.78	1.91	1.04	1.34	.03	.68	.60
	1911	1.20	1.15	.70	.45	2.76	4.61	2.77	2.79	3.14	.34	.63	.70
	1912	.70	.13	.10	.67	.60	1.65	3.32	2.01	2.01	.52	.70	.32
	1913	1.10	.80	.50	.25	.32	3.22	1.99	1.48	.52	.20	.20	.00
	1914	1.45	.38	.39	.31	3.00	5.83	.15	2.49	.38	2.46	1.66	2.00
	Average for 18 years	.44	.32	.72	.53	1.79	.97	.91	1.91	1.13	1.33	.73	.43
Calgary	1907	.40	.20	.76	1.79	1.04	3.76	.85	3.34	2.49	.15	.08	.10
	1908	.08	.29	.55	.87	4.59	7.26	1.73	1.52	.58	.55	.03	.20
	1909	.58	.36	.68	1.14	4.87	2.07	4.09	.59	.36	.64	.21	.44
	1910	.21	.88	1.12	.30	1.08	1.54	.44	3.97	1.50	.48	.34	.17
	1911	.44	.56	1.04	1.06	5.03	2.63	2.17	4.36	.89	.51	.61	.17
	1912	.60	.08	.34	2.05	1.42	4.31	5.20	2.75	2.80	1.09	.68	*
	1913	1.28	.56	.50	.21	2.27	3.91	.61	5.19	.87	.66	.97	*
	1914	.93	.27	.76	.60	.52	2.64	2.52	2.18	1.11	1.82	2.73	.75
	Average for 29 years	.46	.55	.74	.69	2.48	3.27	2.61	2.52	1.24	.50	.72	.54
Banff	1907	1.64	.56	1.55	1.63	3.33	2.80	1.90	4.26	2.62	.96	1.22	1.11
	1908	1.10	1.03	1.58	1.66	4.14	2.61	1.06	1.74	1.41	1.87	1.18	1.71
	1909	3.94	1.38	.78	.92	1.49	1.81	2.68	.99	1.18	.70	4.67	1.02
	1910	.46	1.94	1.59	1.19	.63	2.77	.46	2.97	1.06	1.36	.99	.90
	1911	3.12	.65	.54	1.15	1.35	2.84	1.38	3.76	1.14	.56	1.64	1.04
	1912	.94	.20	.32	1.35	1.06	3.02	5.03	3.94	1.03	1.81	1.41	.37
	1913	1.21	.45	1.42	1.58	1.34	2.29	.91	2.85	2.24	1.23	2.38	.05
	1914	2.54	.25	.90	1.90	1.46	1.81	1.11	.59	2.56	1.69	2.60	.28
	Average for 18 years	1.12	.81	1.48	1.06	2.69	3.47	2.66	2.37	1.75	1.14	1.67	1.17

* Trace of precipitation, too small to measure.

MONTHLY PRECIPITATION (in inches)—ALBERTA.—*Continued*

Place	Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Didsbury	1907	1.30	.60	1.00	.90	1.70	5.33	3.93	4.49	7.03	.43	.00	.40
	1908	*	*	1.00	.55	3.63	10.38	1.77	2.15	.15	1.86	.00	.40
	1909	.25	.40	.90	1.45	4.11	3.79	5.19	1.10	1.06	1.59	.35	.80
	1910	.30	1.00	.70	.00	1.20	4.19	1.95	5.25	1.84	.45	.70	.40
	1911	.30	.40	1.55	1.00	3.90	4.50	2.63	6.47	1.43	.92	.65	.50
	1912	.10	.10	.40	1.62	2.89	2.68	5.46	3.95	2.23	1.91	.70	.20
	1913	1.30	.50	1.00	.30	1.74	8.98	1.19	3.62	.34	.36	.50	.00
	1914	1.30	.40	.80	.40	.79	3.74	1.55	2.11	2.46	1.50	1.70	.60
	Average for 12 years	.40	.45	.81	.85	3.24	5.30	2.85	3.78	1.74	1.04	.62	.41
Edmonton	1907	1.04	.27		.49	1.60	3.09	2.79	4.66	1.32	.19	.11	.56
	1908	.31	.57	1.17	.57	2.58	5.36	2.33	1.71	.59	1.48	.91	.31
	1909	.49	.49	.11	.91	2.96	1.85	3.25	.89	.06	.30	1.23	.34
	1910	.16	.46	.77	.38	1.20	2.72	2.25	2.87	2.01	.51	.67	.93
	1911	1.18	.31	.39	.45	1.95	3.80	5.83	4.49	.98	.51	.52	.26
	1912	1.15	.16	.40	1.57	2.35	3.03	4.76	4.41	1.12	.73	.40	.10
	1913	2.49	.63	.55	1.02	.79	3.66	4.35	4.81	.50	.50	.06	.18
	1914	1.04	1.07	.35	.38	1.81	8.53	3.24	2.52	2.94	1.07	.85	1.49
	Average for 30 years	.71	.74	.77	.84	1.76	3.41	3.75	2.32	1.50	.76	.85	.80
Athabaska	1908									.60	1.20	.67	.85
	1909	.85	.20	.70	1.30	3.24	2.52	2.11	1.01	.07	.57	2.05	.60
	1910		.55	.03	.71	1.12	3.04	4.82	2.11	1.85	1.41	.50	1.04
	1911	.92	.48	1.16	.34	1.87	5.48	2.30	2.02	1.38	.38	.50	.20
	1912	.65	.26	.50	1.13	.72	1.72	2.65	2.56	.72	.74	.23	.54
	1913	1.35	.40	.49	.92	.79	4.82	6.81	2.64	.60	.68	.25	.10
	1914	.53	.12	.66	.43	.17	7.05	2.82	1.31	1.63	1.63	.27	1.07
	Average for 6 years	.86	.34	.59	.81	1.32	4.11	3.59	1.94	.98	.94	.64	.63
Peace River Crossing	1908	.10	.22	1.20	.21	1.33	2.92	2.38	1.84	1.35	.63	.15	.65
	1909	1.20	.50	.15	.81	2.65	1.35	1.54	1.71	1.02	.90	1.80	.40
	1910	.28	.08	.70	.50	1.54	1.98	1.70	1.24	1.15	.27	.65	1.06
	1911	1.65	.40	.50	.15	1.29	2.67	4.08	1.76	3.02		.75	.90
	1912	.80	.15	.30	.95	.80	.71	1.24	1.24	.59	.59	.30	.95
	1913	2.10	1.85			1.60	5.08	1.01	2.91	.77	1.10	.30	.60
	Average for 6 years	1.02	.53	.57	.52	1.53	2.45	1.99	1.78	1.32	.70	.66	.76
Fort Chipewyan	1908	.60			.65								
	1909	.80		1.04		1.90	1.21	1.37	1.52	.43	.50	1.10	.55
	1910	.30	.15	.57	.30	1.19	2.97	3.41	.59	1.93	.59	.30	.30
	1911	*	.15	.86	.38	.28	1.94	1.79	2.57	.39	.24	.60	.65
	1912	.10	.40	.70	1.03	.75	2.31	.58					
	Average for 10 years	.79	.54	.70	.53	.64	1.44	2.68	1.79	1.32	.81	.86	.67

* Trace of precipitation, too small to measure.

MONTHLY PRECIPITATION (in inches)—ALBERTA.—*Continued*

Place	Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Fort Vermilion	1908	.83	.25	.73	1.27	.33	2.72	2.05	1.56	.87	.46	1.33	.23
	1909	.78	.20	.73	1.15	2.06	.97	2.43	1.96	1.25	.47		*
	1910	.20	.20	1.12	.83	.50	1.30	.84	.85	.98	.40	.85	1.18
	1911	.91	.35	1.45	1.85	.73	2.81	1.81	1.96	1.78	.15	.75	.23
	1912	.15	.60	.10	.74		.25	.53	3.32	.90	.70	.57	1.60
	1913	.30	.40	.30	.30	1.88	.69	.51	.53	1.89	.10	.30	.40
	1914		.50				3.00	.67	3.48	1.38			
	Average for 8 years	.47	.37	.77	.87	.84	1.78	1.63	1.52	1.33	.42	.73	.52

* Trace of precipitation, too small to measure.

MONTHLY PRECIPITATION (in inches) YUKON AND NORTHERN BRITISH COLUMBIA

Place	Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.
Ft. St. John, B. C.	1910	.25	.41	.93	.40	.93	1.89					1.45	.43
	1911	.75	.55	.65	.90	2.03	1.01	1.53					
Carcross, Y.T.	1907	*	3.49	.53	.13	*	.03	.43	1.45	.54	.80	1.71	.88
	1908	.29	.45	1.35	.07	.15	0.48	0.22	0.41	1.84	1.01	1.45	.28
	1909	.40	.38	1.23	.33	.47	.55	1.44	1.42	1.68	1.55	.92	.40
	1910	.54	.63	.96	.89	.28	1.18	3.28	.92	.27	.43	.96	1.11
	1911	.65	1.73	.58	.35	1.38	.72		1.31	1.12	1.12	1.28	.79
	1912	.48	.60	.10	.80	.04	.61	1.17	1.85	.47	.41	.68	.94
	1913	1.42	1.03			.28	1.01	1.45	1.01	1.30	2.70	1.63	1.60
	1914	.70	.55	.56		.7	.49	1.02	.45	1.89	.34	.63	.15
	Average for 8 years	.56	1.11	.76		.41	.63	1.29	1.10	1.14	1.05	1.16	.77
Dawson, Y.T.	1907	1.53	.34	.88	.23	1.06	.85	1.93	1.28	2.34	4.09	2.60	.62
	1908	.71	1.00	.71	.32	1.43	1.23	2.43	1.08	1.25	.69	1.48	1.96
	1909	.30	.48	1.21	.64	.81	2.66	2.10	.81	2.40	.96	.67	1.17
	1910	1.31	.22	.68	1.68	.19	1.44	.82	1.67	1.34	1.67	1.46	.60
	1911	1.52	.91	.77	1.30	1.68	.87	1.37	1.39	.86	1.60	1.05	1.70
	1912	.20	1.05	.60	.00	.38	.75				2.43	1.12	2.09
	1913	.67	1.12			.25		.60	.07	1.20	.10	.82	1.45
	1914		.95			1.04	1.73	1.73	1.59	1.21	.10	.70	.08
	Average for 12 years	.88	.69	.53	.53	1.01	1.12	2.02	1.58	1.90	1.32	1.17	1.15
White Horse, Y.T.	1907	.55	.52	1.45	.08	.27	3.03	5.10	1.63	.86	.26	.90	.30
	1908	.10	.08	.23	.01	1.40	0.72		0.47	1.70	1.75	.85	.45
	1909	.45	.30	.40	2.55	.64	.87	1.98	2.34	1.37	1.10	.30	.08
	1910	.18	.06	.30	.02	.03	.66	4.67	1.36	.50	.10	.33	
	Average for 4 years	.32	.24	.59	.67	.58	1.32	3.92	1.45	1.11	.80	.59	.28

* Trace of precipitation, too small to measure.

Appendix VI.

Water-Power Legislation

The rivers and streams of Manitoba, Saskatchewan, Alberta and the Northwest Territories are under the control of the Dominion Government. The disposal and use of the water-powers in these provinces and territories are regulated by Section 35 of the Dominion Lands Act, and by regulations established thereunder by Orders-in-Council.

The following is the text of Section 35 of the Dominion Lands Act of 1908 as subsequently amended, followed by a copy of the Water-power Regulations* made under provisions of Subsection 2 of above section.

Dominion Lands Act

Section 35, Dominion Lands Act, 7-8 Edward VII, Chapter 20, as amended by Section 6, Chapter 27, of 4-5 George V.

35. Lands which are necessary for the protection of any water supply or lands upon which there is any water-power, or which border upon or being close to a water-power will be required or useful for the development and working of such water-power, shall not be open to entry for homestead, for purchased homestead, or pre-emption, or be sold or conveyed in fee by the Crown, but may only be leased under regulations made by the Governor in Council.

2. Subject to rights which exist or may be created under the Irrigation Act, the Governor in Council may make regulations: (*a*)

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* These regulations were made to apply to all forest reserves and parks by order of His Excellency the Governor-General in Council dated June 6, 1911, and by order of His Royal Highness the Governor-General in Council dated August 2, 1913, in virtue of the provisions of subsection (*b*) of section 17 of the Dominion Forest Reserves and Parks Act.

These regulations were made to apply to all school lands by order of His Royal Highness the Governor-General in Council, dated the 9th of February, 1915.

By virtue of the provisions of the Railway Belt Water Act, 2 George V, Chapter 47, and the Railway Belt Water Act, 1913, 3-4 George V, Chapter 45, all water within the Railway Belt of British Columbia is administered under and in accordance with the provisions of the Water Act, 1909, and amendments thereto, by the Province of British Columbia, except only the territory included within Dominion Parks.

for the diversion, taking or use of water for power purposes, and the granting of the rights to divert, take and use water for such purposes, provided that it shall be a condition of the diversion or taking of water that it shall be returned to the channel through which it would have flowed if there had been no such diversion or taking, in such manner as not to lessen the volume of water in the said channel; (*b*) for the construction on or through Dominion or other lands of sluices, races, dams or other works necessary in connection with such diversion, taking or use of water; (*c*) for the transmission, distribution, sale and use of power and energy generated therefrom; (*d*) for the damming of and diversion of any stream, watercourse, lake or other body of water for the purpose of storing water to augment or increase the flow of water for power purposes during dry season; (*e*) for fixing the fees, charges, rents, royalties or dues to be paid for the use of water for power purposes, and the rates to be charged for power or energy derived therefrom.

3. Any person who under such regulations is authorized to divert, take or use water for power purposes, or to construct works in connection with the diversion, taking or use of water for such purposes, shall for the purposes of his undertaking have the powers conferred by the Railway Act upon railway companies, including those for the acquisition and taking of the requisite lands, so far as such powers are applicable to the undertaking and are not inconsistent with the provisions of this Act or the regulations thereunder, or with the authority given to such persons under such regulations—the provisions of the said Railway Act giving such powers being taken for the purposes of this section to refer to the undertaking of such person where in that Act they refer to the railway of the railway company concerned.

4. All maps, plans and books of reference showing lands other than Crown land necessary to be acquired by any such person for right of way or other purposes in connection with his undertaking shall be signed and certified correct by a duly qualified Dominion land surveyor.

5. Such maps, plans and books of reference shall be prepared in duplicate, and one copy thereof shall be filed in the office of the Minister at Ottawa, and the other shall be registered in the land titles office for the registration district within which the lands affected are situated.

6. The Minister, or such officer as he designates, shall in case of dispute, be the sole and final judge as to the area of land which may be taken by any person without the consent of the owner for any purpose in connection with any water-power undertaking.

WATER-POWER REGULATIONS

Regulations established and approved by His Excellency the Governor-General in Council dated June 2, 1909, June 8, 1909, April 20, 1910, January 24, 1911, June 6, 1911, August 12, 1911, and by His Royal Highness the Governor-General in Council dated August 2, 1913, and February 9, 1915, in virtue of the provisions of subection 2 of section 35, of the Dominion Lands Act, 7-8 Edward VII, Capter 20, and of the provisions of subsection (*b*) of section 17 of the Dominion Forest Reserves and Parks Act, 1-2 George V, Chapter 10, to govern the granting and administration of water-power rights in the provinces of Manitoba, Saskatchewan and Alberta, and in the Northwest Territories, and in Dominion Parks within the Railway Belt of British Columbia, and of all school lands.

Definition of Works

1. Under these regulations the word "works" shall be held to mean and include all sluices, races, dams, weirs, tunnels, pits, slides, flumes, machines fixed to the soil, buildings and other structures for taking, diverting and storing water for power purposes, or for developing water-power and rendering the same available for use.

Mode of Application

2. Every applicant for a license to take and use water for power purposes shall file with the Minister of the Interior a statement in duplicate setting forth:—

(*a*) The name, address and occupation of the applicant.

(*b*) The financial standing of the applicant so far as it relates to his ability to carry out the proposed works.

(*c*) The character of the proposed works.

(*d*) The name, or if unnamed, a sufficient description of the river, lake or other source from which water is proposed to be taken or diverted.

(*e*) The point of diversion.

(*f*) The height of the fall or rapid of such river, lake or other source of water at high, medium and low stages, with corresponding discharges of water per second, reckoned approximately in cubic feet.

(*g*) A reasonably accurate description, and the area, of the lands required in connection with the proposed works, such lands, if in surveyed territory, to be described by section, township and range, or river or other lot, as the case may be, and a statement whether such lands are or are not Dominion lands.

(*h*) If such lands be not Dominion lands, then the applicant shall give the name of the registered owner in fee, and of any registered mortgagee or lessee thereof, and of any claimant in actual possession other than a registered owner, mortgagee or lessee.

(*i*) The minimum and maximum amount of water-power which the applicant proposes to develop, and the maximum amount of water which he desires for such purpose.

(*j*) Sketch plan showing approximate locations of the proposed works.

(*k*) Elevations of head water and tail water of the nearest existing works, if any, below and above the proposed works.

(*l*) Particulars as to any water to be taken, diverted or stored to the detriment of the operation of existing works, if any.

(*m*) Particulars as to any irrigation ditches or reservoirs, or other works for irrigation within the meaning of *The Irrigation Act,* in use or in course of construction within the vicinity of the proposed works, and which might affect or be affected by the operation of the proposed works.

Application by a Company

3. If the applicant be an incorporated company, the statement shall, in addition to the foregoing information, set forth,—

(*a*) The name of the company.

(*b*) The names of the directors and officers of the company and their places of residence.

(*c*) The head office of the company in Canada.

(*d*) The amount of subscribed and paid-up capital, and the proposed method of raising further funds, if required, for the construction and operation of the proposed works.

(*e*) Copy of such parts of the charter or memorandum of association as authorize the application and proposed works.

Application by a Municipality

4. If the applicant be a municipality, then, excluding the special information to be given by a company, the following information shall be given:—

(*a*) The location, area and boundaries of the municipality.

(*b*) The approximate number of its inhabitants.

(*c*) The present estimated value of the property owned by such municipality, and the value of the property subject to taxation by such municipality.

Minister may Request Further Information

5. The Minister of the Interior shall have the power to call for such other plans and descriptions, together with such measurements, specifications, levels, profiles, elevations and other information as he may deem necessary, and the same shall be furnished by and at the expense of the applicant.

The Agreement for,—(*a*) A license for the diversion and use of water. (*b*) A lease of the necessary lands.

Agreement for License or Lease

6. Upon receipt and consideration of the application, and information accompanying same, the Minister of the Interior may, if he approves of the proposed works, enter into an agreement with the applicant, which agreement, in addition to usual conditions and covenants, shall contain clauses to provide as follows:—

(*a*) For a time within which the proposed works shall be begun.

(*b*) For a stated minimum amount of expenditure to be made in connection with the works annually during the term of the agreement.

(*c*) For a stated amount of water-power to be developed from the water applied for within a fixed period not exceeding five years.

(*d*) For summary cancellation of the agreement by the Minister if any of the above conditions have not been complied with.

(*e*) For defining and allotting the areas of Dominion lands within which the applicant may construct and operate the proposed works; and if there be no Dominion lands available for such purpose then for defining and allotting the lands in regard to which the applicant may exercise the powers given under section 35, subsection 3, of the *Dominion Lands Act.*

(*f*) For granting a license to the applicant, upon fulfilment of the said agreement, to take, divert and use for power purposes a stated maximum amount of water, in accordance with the application, and plans and specifications as approved by the Minister; the term of such license to be twenty-one years at a fixed fee payable annually, and such license to be renewable as provided for in these regulations.

(*g*) For granting a lease to the applicant of such Dominion lands as may be allotted under paragraph (*e*) of this section, and approved of by the Minister, such lease to be at a fixed rental, for a term of twenty-one years running concurrently with the said license, and renewable in like manner, and as near as may be subject to all the terms and conditions thereof. When there are no Dominion lands available for such

purpose, or when other lands are considered by the Minister to be more suitable for such purpose, then the Minister shall define such lands in regard to which the applicant may exercise the powers given under section 35, subsection 3, of the *Dominion Lands Act.*

Inspection of Construction Work

7. During the construction of any works for the development of water-power the Minister of the Interior, or any engineer appointed by him for that purpose, shall have free access to all parts of such works for the purpose of inspecting same, and ascertaining if the construction thereof is in accordance with the plans and specifications approved of by the Minister, and whether the terms of the agreement, as provided for in the preceding section, are being fulfilled.

License for Diversion and Use of Water

8. Upon fulfilment by the applicant of the conditions of the said agreement, the Minister of the Interior shall grant to the applicant a license as agreed upon, and such license shall contain clauses to provide as follows:—

(*a*) The term of the license shall be twenty-one years, renewable for three further consecutive terms of twenty-one years each, at a fixed fee payable annually and to be readjusted at the beginning of each term, as hereunder provided.

(*b*) At the expiry of each term of twenty-one years the Governor in Council may, on the recommendation of the Minister, order and direct that the license and any lease granted in connection therewith be cancelled: Provided that the Minister shall have given at least one year's notice to the licensee of intention so to cancel.

(*c*) If the licensee shall refuse to pay the license fee as readjusted by the Governor in Council, or as fixed by arbitrators chosen as provided in paragraph (*e*) hereunder, then in such case the Minister may renew the license at the former fee, or the Governor in Council may, on the recommendation of the Minister, order and direct that the license and any lease issued in connection therewith be cancelled.

(*d*) In either of the above cases compensation shall be paid to the licensee as provided for in paragraph (*e*) hereunder.

(*e*) On termination of the third renewal of such license, except in case of default on the part of the licensee in observance of any of the conditions thereof, or of any lease granted in connection therewith, compensation shall be paid for the works to the amount fixed by arbitration, one arbitrator to be appointed by the Governor in Council, the second by the

licensee, and the third by the two so appointed. If the licensee fails to appoint an arbitrator within ten days after being notified by the Minister to make such appointment, or if the two arbitrators appointed by the Governor-General in Council and the licensee fail to agree upon a third arbitrator within ten days after their appointment, or within such further period as may be fixed by the Minister, in either such cases such arbitrator or third arbitrator, as the case may be, shall be appointed by the Judge of the Exchequer Court of Canada. In fixing the amount of compensation only the value of the actual and tangible works and of any lands held in fee in connection therewith shall be considered, and not the value of the rights and privileges granted, or the revenues, profits or dividends, being, or likely to be derived therefrom.

(*f*) The license shall state the maximum amount of water which the licensee may divert, store and use for power purposes, and shall provide for the return to the stream, or other source of water, of the full amount so diverted.

(*g*) The licensee shall develop such power as, in the opinion of the Minister, there shall be a public demand for, up to the full extent possible from the amount of water granted by the license.

(*h*) Upon a report being made by the Minister of the Interior to the Governor in Council that the licensee has not developed the amount of power for which there is a public demand, and which could be developed from the amount of water granted by the license, the Governor in Council may order to be developed and rendered available for public use the additional amount of power for which there is, in the opinion of the Minister, a public demand, up to the full extent possible from the amount of water granted by the license, and within a period to be fixed by the Minister, which period shall not be less than two years after the licensee or person in charge of the existing works shall have been notified of such order, and in default of compliance with such order the Governor in Council may direct that the license, together with any lease issued under these regulations, shall be cancelled, and the works shall thereupon vest and become the property of the Crown without any compensation to the licensee.

(*i*) Upon a report being made by the Minister of the Interior to the Governor in Council that a greater amount of water-power could be developed advantageously to the public interests from the same stream or other source of water from

which the existing works derive power and (1st) that the existing works could be enlarged or added to for such purpose, then the Governor in Council may authorize the Minister to offer the licensee the privilege of constructing and operating such enlarged or additional works at or in the vicinity of the existing works, and to grant such supplementary license as he may consider proper for such purpose, and if the licensee fail within six months thereafter to accept such offer, and in good faith to begin and carry on to completion such enlarged and additional works, and to complete same in accordance with plans and specifications approved of by the Minister, and within a fixed period not to exceed five years, and upon like conditions as the existing works were begun and completed; or (2nd) if the Minister shall report to the Governor in Council that the existing works, owing to their location or construction, cannot advantageously be enlarged or added to in order to develop further power sufficient to meet the probable demand, or would be a hindrance to other works contemplated for such purpose; or (3rd) that the existing works cannot, or will not, be any longer advantageously operated owing to the exercise of rights existing or created under the *Irrigation Act;* then in every such case, the Governor in Council may order and direct that the license, and any lease in connection therewith, and all rights thereunder, shall be cancelled, and the existing works shall thereupon vest in and become the property of the Crown: Provided always that in every such case compensation shall be paid to the licensee as provided for in paragraph (*e*) of section 8 of these regulations, together with a bonus apportioned as follows:—

(1) If the works have been in operation less than five years, a thirty per cent bonus upon the value of the works.

(2) If in operation more than five years, and less than ten years, a twenty-five per cent bonus.

(3) If in operation more than ten, and less than fifteen years, a twenty per cent bonus.

(4) If in operation more than fifteen, and less than twenty years, a fifteen per cent bonus.

(5) If in operation twenty years or more, a ten per cent bonus.

(*j*) That the license shall not be transferable without the written consent of the Minister, and that if the licensee fail to keep and observe all or any of the conditions of the license, or any renewal thereof, or of any lease to be issued in connection

therewith, then the license, together with such lease, shall in every such case be subject to cancellation by the Exchequer Court on the application of the Crown.

(*k*) That a schedule of rates and prices to be charged to the public for the use of power shall first be submitted by the licensee to the Board of Railway Commissioners of Canada for adjustment and approval before being put into effect, and that no rates or prices for power shall be legal or enforceable until such schedule has been so adjusted and approved nor if they shall exceed the amount fixed by such schedule; and that such schedule shall be readjusted and approved by the Board every seven years during the term of the lease and license, and all renewals thereof.

(*l*) That for the purpose of ascertaining the quantity of power actually developed, or capable of being developed, from the amount of water granted by such license, the Minister, or any engineer appointed by him for that purpose, shall have free access to all parts of the works, and to all books, plans or records in connection therewith, bearing on the quantity of power developed, and may make measurements, take observations and do such other things as he may consider necessary or expedient for such purpose, and the findings of the Minister, or such engineer, thereon shall be conclusive and binding upon the licensee.

(*m*) For the proper provision, as required by law, for the passage of logs and timber down the stream or other waterway affected by the works.

(*n*) For the erection and maintenance by the licensee of a durable and efficient fishway in the stream or other waterway affected by the works when so required by the proper officer or authority in that behalf.

(*o*) That the licensee shall have no right to any water beyond the amount stated in the license.

(*p*) For the indemnifying of the Crown against all actions, claims or demands against it by reason of anything done by the licensee in the exercise, or purported exercise, of the rights and privileges granted under the lease or license.

9. The agreements and licenses to be issued hereunder shall, subject always to the provisions of these regulations, be in such form and contain such provisions as the Minister may from time to time determine.

Storage of Water

10. If at any time it is proposed by the applicant or the licensee to divert water from any lake or body of water for storage purposes, or to dam same in order to augment the flow of water in any stream from which water-power is to be developed, the applicant or licensee shall, in addition to other information required under these regulations, file plans as follows:—

(*a*) A general plan in duplicate, on tracing linen, showing the location of such lake or other body of water, and the lands to be submerged or otherwise affected, and contour lines showing the water level at high and low stages, and the level to which it is proposed to raise such water for storage, and the estimated storage capacity of such lake or other body of water.

(*b*) A plan in duplicate, from actual survey, by a Dominion land surveyor, and certified to by him, showing the lands to be submerged or otherwise affected by the proposed storage; the name of the registered owner in fee of such lands, and of any registered mortgagee or lessee thereof, and of any claimant in actual possession other than a registered owner, mortgagee or lessee.

(*c*) A detail plan in duplicate on tracing linen, showing all dams and other works proposed to be constructed in connection with such storage.

11. When the plans for such storage of water have been approved of by the Minister of the Interior, provision for same shall be made in the agreement for a license, or in the license itself, or in a supplementary license to be issued for such purpose, upon such terms and conditions as may appear to the Minister reasonable or expedient in the circumstances of each case, and subject to these regulations.

Small Water-powers

12. If upon receipt and consideration of the information set out in sections 2, 3, 4 and 5, the water-power to be developed is found to have no greater capacity than 200 horse-power at the average low stage of water, the Minister may issue a lease and a license as may be required, authorizing the development of the proposed power; the lease and license to be for a period of ten years, subject to such special terms and conditions as may be considered advisable in each particular case and renewable if in the opinion of the Minister the power has been continuously and beneficially used.

APPENDIX VII

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Canada
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JAMES WHITE, ASSISTANT TO CHAIRMAN
1913
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By J. B. Challies, A.M. Can. Soc. C.E.
Superintendent of Water Power Branch, Dept. of Interior
Scale 1/253,440 : 4 Miles to 1 inch
Miles
LEGEND
Storage Basins
Power Sites
Power Plants
Transmission Lines
Sub-station
Limits of basin
BRITISH COLUMBIA
YOHO PARK
ALBERTA
ROCKY MOUNTAINS
BOW RIVER
CALGARY
BANFF
CANMORE
BOW LAKE STORAGE CAPACITY 27,400 Ac. Ft.
DEVELOPED STORAGE 44,700 Ac. Ft.
CASCADE POWER AND STORAGE DAM
CALGARY POWER COMPANY'S PLANTS
KANANASKIS POWER AND STORAGE DAM SITE
KANANASKIS RIVER STORAGE CAPACITY 8,000 Ac. Ft.
SPRAY LAKE STORAGE CAPACITY 171,000 Ac. Ft.
ELBOW RIVER DAM SITE
ELBOW RIVER STORAGE CAPACITY 23,000 Ac. Ft.
CALGARY POWER CO. SUB STATION
STONEY INDIAN RESERVE
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GOAT RANGE
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FISHER RANGE
Kananaskis Lakes
Lake Minnewanka
CANADIAN PACIFIC RAILWAY


Commission of Conservation
Canada
SIR CLIFFORD SIFTON, K.C.M.G. CHAIRMAN
JAMES WHITE, ASSISTANT TO CHAIRMAN
1915
WATER POWERS
IN
MANITOBA, SASKATCHEWAN,
ALBERTA, YUKON
AND
NORTH WEST TERRITORIES
Scale
Reference numbers in List of Water Powers (see Report)
WATER-POWERS
YUKON
WATER-POWERS
NORTH WEST TERRITORIES
ALBERTA
SASKATCHEWAN
MANITOBA
LAKE ATHABASKA
GREAT SLAVE LAKE
ROCKY MOUNTAINS
CALGARY
Chipewyan
Port Nelson
York Factory